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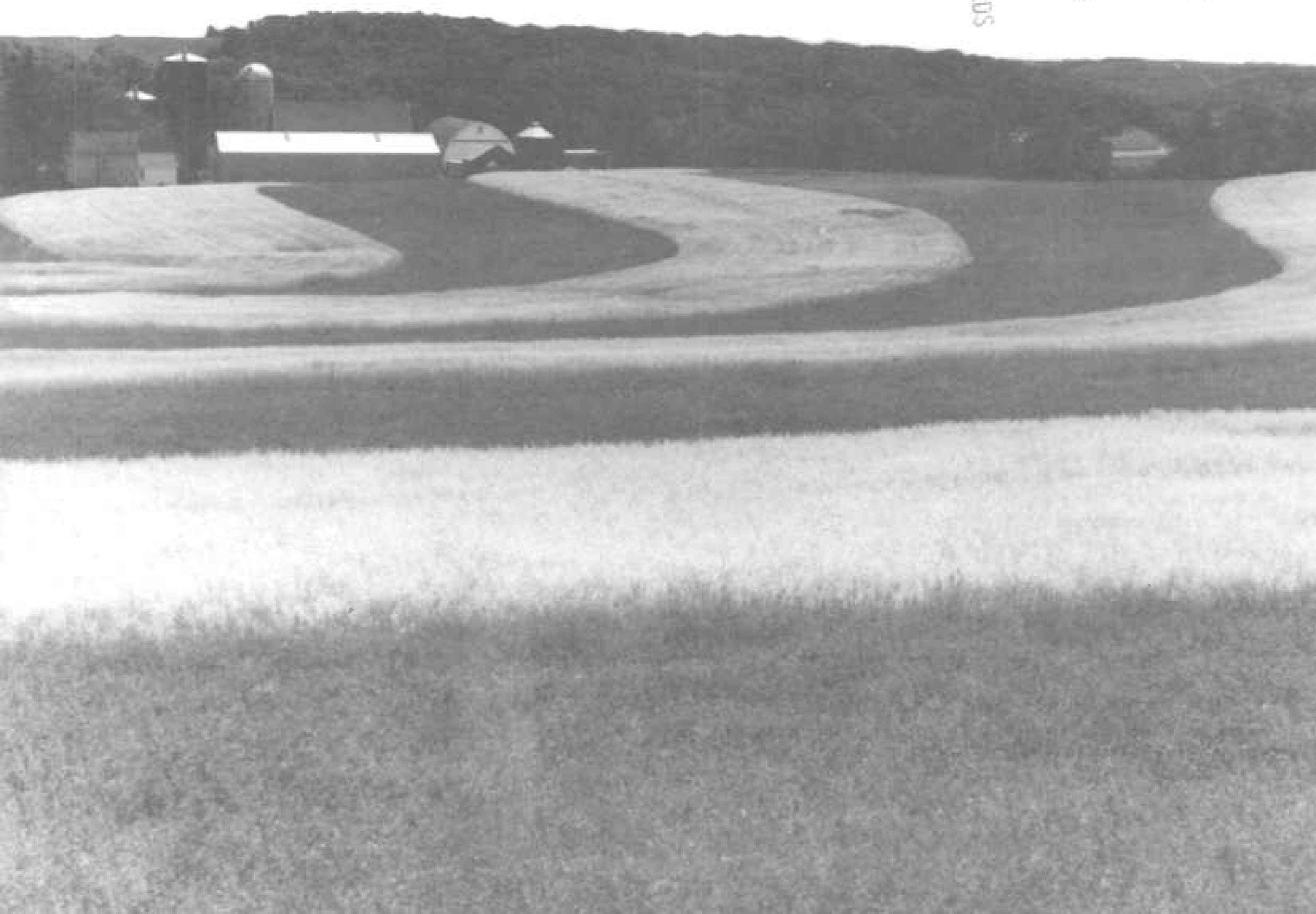
An Economic Analysis of USDA Erosion Control Programs

A New Perspective



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An Economic Analysis of USDA Erosion Control Programs: A New Perspective. Roger Strohbehn (Editor), Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 560.

ABSTRACT

Soil conservation programs would be more effective if they focused more on controlling erosion on highly erodible land. Significant effort and funding for current programs are directed to cropland that erodes at less than 5 tons per acre per year. Yet, the benefits of erosion control measures exceed the costs involved only on land eroding at about 15 tons per acre per year and above. More benefits from controlling erosion on cropland are offsite, realized away from the cropland itself, indicating the significance of public benefits from soil conservation efforts.

Keywords: Soil conservation, soil productivity, offsite benefits, benefit-cost analysis, cropland, erosion.

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Preparation of this report was coordinated by Roger Strohbehn. A team of agricultural economists was responsible for conducting the analyses and presenting findings from the study. The team included William D. Anderson, Alexander Barbarika, Daniel Colacicco, Ralph Heimlich, Linda Lee, Craig Osteen, George Pavelis, Marc Ribaudo, Neill Schaller, Gary Taylor, and C. Edwin Young. Contributions of these staff members to the report are noted in the text.

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PREFACE

This study was undertaken to analyze the economic benefits and costs of current soil conservation programs and to provide information to improve their economic effectiveness in reducing long-term soil productivity losses and offsite damages. Program costs included private costs plus Federal, State, and local government expenditures for erosion control. Benefits include the reduction of offsite damages from soil erosion, and avoidance of long-term productivity losses net of the short-term production benefits that are often a joint product of conservation investments.

The results presented here represent the first comprehensive, nationwide analysis of the economic benefits from erosion control expenditures. New analytical procedures were developed for the study and new sources of data were used to estimate both benefits and costs of erosion control programs. Because offsite and joint production benefit data were sometimes incomplete and cost data were of uneven quality, ranges as well as mid-level estimates are presented. In view of these data limitations, the results of this economic analysis of conservation program activities are only meant to provide an indication of potential improvements in economic efficiency. The results provide some valuable new insights and understandings about conservation program management and underscore the need for better economic information and research to increase program effectiveness.

The results are consistent with previous cost effectiveness studies of conservation cost-sharing programs administered by the Agricultural Stabilization and Conservation Service and conservation technical assistance provided by the Soil Conservation Service. Those studies found that program effectiveness could be significantly increased by shifting conservation efforts to areas with higher levels of erosion. However, adding the economic dimension to benefit estimation, as this study does, indicates the breakeven point for efficient conservation practices to control erosion.

Offsite impacts of erosion control were not addressed in the previous evaluations. This study finds that they may be a substantial part of soil erosion control benefits. In many cases the offsite benefits exceed the costs of public assistance.

This study provides new information on offsite benefits and the joint conservation and production benefits resulting from conservation investments, and reveals new insights into the nature of conservation programs. It illustrates the importance of improving the quality and completeness of both the benefit and cost data so that more reliable information will be available to improve the effectiveness of conservation programs in the future.

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SUMMARY

Public and private expenditures of nearly $420 million were made for erosion control on 16.5 million acres of cropland in 1983, protecting soil productivity and reducing offsite damage. Offsite benefits, such as enhanced fishing and recreation activities and reduced sediment removal costs for navigation, accounted for significant erosion control benefits. Our analysis shows benefits exceeding costs on cropland with erosion rates of about 15 tons per acre per year. We found that targeting erosion control to more highly erodible land would increase the efficiency of conservation funds.

Those findings are based on a new, nationwide analysis of the total (public and private) costs and benefits of three major USDA erosion control programs: the Conservation Technical Assistance Program, administered by USDA's Soil Conservation Service (SCS); the Great Plains Conservation Program, also administered by SCS; and the Agricultural Conservation Program, administered by USDA's Agricultural Stabilization and Conservation Service.

The study estimates the economic rate of return to erosion control expenditures on cropland as reflected in soil productivity and offsite damage reduction benefits. It goes beyond earlier evaluations, which focused on the reduction in the physical tons of erosion and on the least cost ways of achieving erosion reduction goals. In doing so, the study has confronted but not eliminated previous technical barriers to accurate economic measurement of program efficiency. Consequently, the results are only indicative of the general magnitude of costs and benefits associated with cropland erosion control. These provisional findings nevertheless suggest possible ways to increase the payoff from the USDA's erosion control programs:

- o Target public conservation funds to land with the highest erosion rates. Forty percent of the cropland receiving program assistance was eroding at only 5 tons per acre per year or less.

- o Give increased recognition to offsite benefits. Offsite benefits may account for two-thirds of total erosion control benefits.

- o Provide conservation assistance based on the economic value of soil productivity loss and the value of reducing offsite damages rather than simply on physical erosion rates. These values differ among soils and across geographic areas.

- o Expand the Conservation Reporting and Evaluation System (CRES) to include data for estimating the full economic consequences and costs of conservation practices. Cost effective program implementation requires reliable estimates of shortrun production and income benefits, longrun soil productivity benefits, and offsite benefits.

Our findings must be interpreted in light of the following technical limitations of the analysis and data:

- o Because some offsite benefits are nonmarket goods whose economic value must be imputed based on secondary data and indirect measurement

procedures, the offsite benefits span a wide range. Also, offsite wind erosion control benefits were excluded because reliable estimates of such benefits were not available.

- Consistent data to allocate conservation tillage costs between the joint goals of saving soil and reducing shortrun production costs were lacking.

- Data were not available to estimate the full onsite economic consequences of all erosion control practices. In particular, estimates of crop damage due to wind erosion were not available, nor were data to estimate the economic impacts of gully erosion. And, the shortrun net income impacts from adopting conservation practices are not fully known. The data were insufficient to estimate all joint shortrun production costs and benefits associated with the adoption of erosion control practices.

Several factors help to explain why the economic efficiency of conservation programs are lower than ideal: The historical lack of economic data and program guidelines for reducing economic damages rather than gross soil erosion, past emphasis on agricultural production and farm income support which has often placed conservation in a secondary role to commodity supply control, the application of conservation measures on land with low erosion rates, and some erosion control practices contributing to water conservation and other conservation objectives whose benefits were not included in the analysis.

An Economic Analysis of USDA Erosion Control Programs

A New Perspective

INTRODUCTION

We now have a half century of experience with federally supported programs for soil conservation. The U.S. Department of Agriculture administers 26 different conservation programs ranging from cost-sharing assistance to research, and serving a variety of conservation purposes ranging from erosion control to energy conservation. Annual Federal expenditures for USDA's conservation programs exceed $1 billion.

The effectiveness of programs in reducing soil erosion and other damage caused by erosion is difficult to gauge. Reflecting the lack of data on effectiveness, Congress passed the Soil and Water Resources Conservation Act of 1977 (53). 1/ This act led to the development of a National Conservation Program that emphasized Federal conservation efforts to reduce excessive soil erosion, conserve water used in agriculture, and reduce upstream flood damages. The act also introduced the concept of targeting Federal conservation assistance to critical problem areas and initiated specific conservation program evaluations to provide more indepth analysis than had been done in the past.

There have been earlier evaluations, including some by USDA, of the effectiveness of public soil conservation programs. However, these evaluations focused mainly on physical, rather than economic, measures of erosion damage. These previous evaluations addressed ways to improve program performance by comparing program accomplishments with the magnitude of erosion problems or by analyzing the cost effectiveness of conservation practices to reduce erosion.

This study builds on the cost effectiveness evaluation studies of the Agricultural Stabilization and Conservation Service and Soil Conservation Service (57, 64). It also responds to the call in a General Accounting Office evaluation report to evaluate erosion control programs in terms of protecting onsite soil productivity and reducing offsite damages (67). This study uses new data compiled by ASCS and SCS and new procedures for estimating relationships between erosion, soil productivity, and offsite damages, to derive the economic value of soil conservation program benefits. The new data and procedures have not been adequately refined to provide

1/ Underscored numbers in parentheses refer to sources listed in the References at the end of this publication.

definitive answers about the economics of erosion control programs. Nevertheless, the broad economic perspective of the study, in conjunction with best available data sets, provides a general indication of the economic benefits and costs of USDA erosion control programs. By comparing economic benefits with program costs, possible ways to improve program performance by reallocating funds or changing priorities can be identified.

Physical measures, such as tons of soil erosion reduced, have been used to approximate the benefits from erosion control actions in previous assessments of the effectiveness of conservation programs. These physical measures, however, provide only part of the information needed to measure economic benefits. Productivity benefits depend on many factors besides total tons of soil erosion reduced by programs. Recent studies suggest, furthermore, that offsite benefits of soil erosion may be more significant than onsite productivity impacts (7). Offsite impacts relating to water quality and sedimentation are also valued according to many factors in addition to the reduction in tons of soil erosion and sediment deposited.

With recent developments in modeling physical relationships between soil erosion and soil productivity, as well as the availability of national estimates of offsite damages due to soil erosion, we can now make an initial assessment of the social benefits and costs of erosion control programs. Our study assesses the average economic efficiency of soil conservation programs on cropland with different rates of erosion by focusing on national benefits and costs of three major USDA erosion control programs.

Specific objectives of our appraisal are:

1. To quantify the productivity benefits of reducing soil erosion on cropland.

2. To determine the offsite benefits of reducing soil erosion on cropland.

3. To compare the cost and benefits of three major soil conservation programs on cropland.

4. To assess the allocation of soil erosion control dollars relative to the magnitude of erosion problems.

5. To identify implications of the benefit-cost analysis for program design and management.

This report focuses on three major erosion control programs on cropland. Our analysis is confined to cropland because no existing models assess physical relationships between soil loss and productivity for pasture, range, and other agricultural lands. The analysis is limited to 1983, the most recent year for which the necessary data were available.

We analyzed three major USDA conservation programs: Conservation Technical Assistance (CTA), Agricultural Conservation Program (ACP) cost-sharing, and the Great Plains Conservation Program (GPCP). The CTA program provides funding for SCS technical assistance to farmers and ranchers for soil conservation measures. The ACP, administered by ASCS, provides long- and short-term agreements for financing soil conservation practices. GPCP is similar to CTA, but offers long-term cost-sharing along with technical assistance to Great Plains farmers. Other conservation programs exist. However, our analysis was confined to these three basic programs because they are the main programs focusing on erosion control.

The three programs accounted for about 40 percent of the $1.18 billion USDA spent for conservation in 1983. Within these programs, only $270 million was allocated specifically to erosion control. Our analysis estimated the economic efficiency in the use of these erosion control funds in conjunction with other public and private investments.

Issues of equity, an important part of the historical justification for soil conservation programs, are not addressed in this study. Soil conservation programs originated during the Great Depression and had employment and income support objectives in addition to erosion control and resource protection goals (36). We limited our analysis to the economic efficiency of public and private outlays for conservation as a means of protecting soil productivity for future generations and reducing offsite damages to benefit downstream water users.

PHYSICAL AND INSTITUTIONAL DIMENSIONS OF SOIL EROSION CONTROL PROGRAMS*

Here we describe the physical nature of the erosion process and characteristics of USDA erosion control programs as a background for understanding the design and structure of our analysis of erosion control programs.

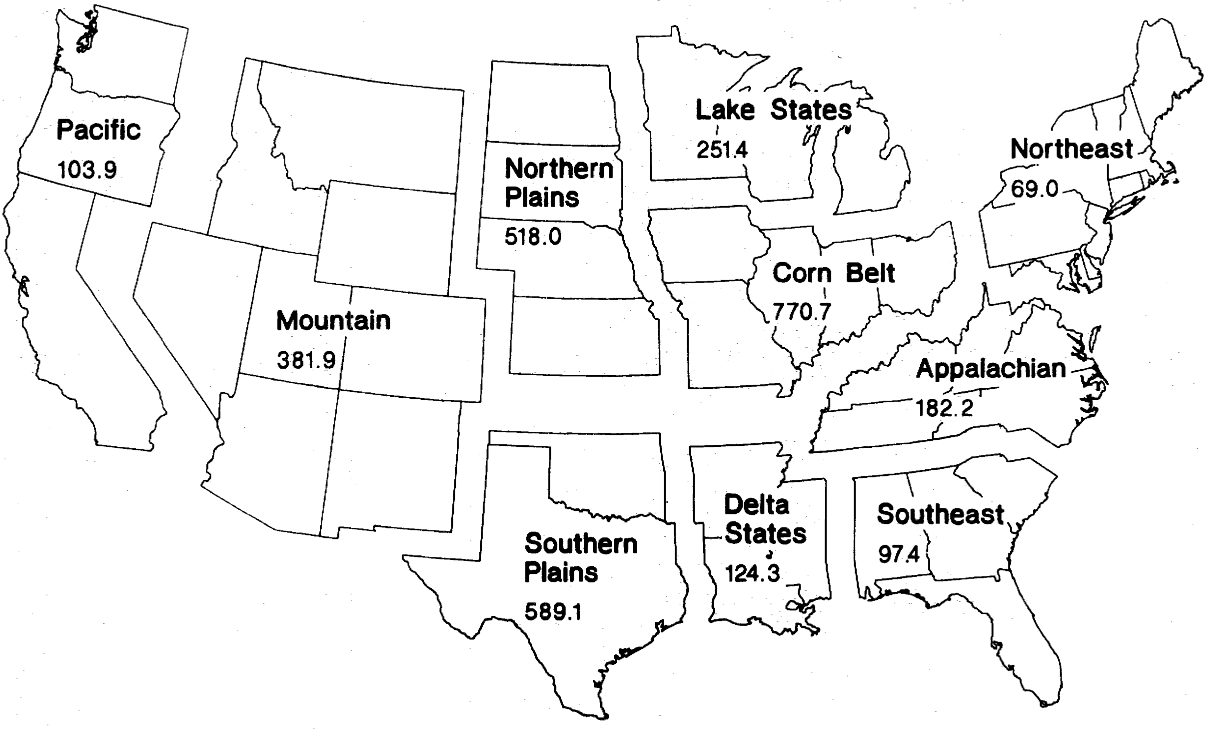
An estimated 5.4 billion tons of soil eroded from rural nonfederal land in 1982, according to the National Resources Inventory (NRI). Sheet, rill, and wind erosion on 421 million cropland acres accounted for 3.1 billion tons, while 1.2 billion tons eroded from 539 million acres of pasture and range land. Erosion on cropland was concentrated in certain regions. The Corn Belt accounted for a quarter of all sheet, rill, and wind erosion on cropland. About 60 percent of all cropland erosion occurred in the Corn Belt and the Northern and Southern Plains (fig. 1).

A relatively small proportion of cropland with high erosion rates is responsible for a large proportion of total soil eroded. Based on the 1982 NRI, 25 percent of cropland suffers sheet and rill erosion rates high enough to damage soil productivity. Up to 5 tons per acre per year (TAY) is generally considered the level of soil erosion that will not damage long-term soil productivity. Only 16 percent of cropland is reported to have wind erosion above tolerable levels. Concentration of high erosion rates on relatively few acres means that nearly three-quarters of the soil lost from sheet and rill erosion comes from only a quarter of all cropland. More than 80 percent of soil lost from wind erosion comes from only 16 percent of the cropland.

*This section was prepared by Ralph Heimlich. Part of the analysis and text were provided by William D. Anderson, George Pavelis, and Marc Ribaudo.

Figure 1

Sheet, rill, and wind erosion from cropland



Numbers show million tons of erosion, 1982.

While physical measures of erosion such as tons per acre are informative and necessary, they are not adequate proxies for the socioeconomic impacts of erosion. Physical measures of erosion were used as proxies in the past because measurement of the economic and social impacts was not possible.

Erosion Processes

Sheet and rill erosion is the most common form of agricultural soil erosion. It occurs when raindrops detach soil particles from the soil surface and transport them in thin sheets of water moving across unprotected slopes. As runoff water becomes concentrated into separate channels, it begins to cut gullies, removing larger volumes of soil.

An ephemeral gully is a short-lived or seasonal incision on the landscape caused by concentrated water runoff. Ephemeral gullies generally occur on cropland, particularly land used for row crops, and are characterized by a branching pattern of enlarged rills that are obliterated or smoothed out by cultivation. These gullies tend to reappear, however, in approximately the same places and in the same pattern during the next period of concentrated runoff. Ephemeral gullies eventually contribute to accelerated erosion over the affected area similar to the soil deterioration associated with sheet erosion. The effects of such gullies have only recently been identified and methods to quantify erosion from this source have yet to be developed. Deep gullies not obliterated by cultivation have long been recognized as an important source of cropland erosion.

When runoff water accumulates into recognizable streams, the cutting process of flowing water continues on the stream banks and the channel bottoms. A similar process occurs along roadside ditches on unpaved roads.

The wind erosion process is truly separable. Wind can detach and transport soil particles, carrying them from a few feet to hundreds of miles. Wind erosion is generally worst under drought conditions when the adhesive action of soil moisture is less.

Water and wind erosion have two major types of impacts: (1) onsite impacts, that is, where the erosion occurs, and (2) offsite impacts, where eroded soil is carried and deposited. Yet another erosion-caused problem is the change or destruction of wildlife habitats, which can take place both on and off the erosion site.

Onsite Impacts

The major onsite effect is usually called the productivity impact. When soil is not deep enough, plant roots are limited and productivity is impaired (16, 28, 35). Many field studies have confirmed differences in crop yields between the eroded and uneroded phases of the same soils (1, 6, 17, 21, 22). For the row crops most important to U.S. agriculture, a rooting depth of about 39 inches is considered critical (35).

In addition to soil depth, the characteristics of the soil are important for plant growth. Many soil characteristics in the thin layer at the soil surface affected by tillage can be modified by soil additives. However, for the roughly 35 inches of root zone below the plow layer, productivity depends on the relatively immutable qualities of the soil. These soil characteristics important to plant growth include root penetration, water-holding capacity, soil acidity (pH), aeration, and electrical conductivity (28, 29). In general, these characteristics are favorable to plant growth in the topsoil and become less favorable in deeper soil layers. As soil erosion strips away the topsoil, the root zone extends deeper and deeper into unfavorable soil layers and productivity declines.

Sheet and rill and wind erosion processes slowly remove topsoil in relatively thin layers. For example, an erosion rate of 10 tons per acre per year translates to about 1/16 inch of topsoil. The branching rills of ephemeral gullies may remove soil in larger quantities, but the process is still a barely perceptible lowering of the soil profile since the rills are filled in and smoothed out with normal tillage. Some ephemeral gully erosion may require replanting costs on small areas where concentrated flows occur and in areas where sediment fans bury young seedlings. The primary onsite impact of nonephemeral gullies is the area lost to crop production by the gully and increased production costs from farming around the gullies. The volume of soil lost may be less important than the area removed from cropping and the increased production costs. Wind erosion can have short-term production impacts through abrasion of leaves and stems as well as long-term loss of soil depth. 2/

Offsite Impacts

The most widespread erosion-caused problem away from the point where soil is lost is impairment of water resource use. Three related causes of water use impairment are sedimentation, eutrophication, and pesticide contamination.

When soil particles and agricultural chemicals wash off a field, they may be carried in runoff until discharged into a water body or stream. Not all agricultural pollutants that erode from a field reach water systems, but a significant portion does, especially dissolved chemicals and the more chemically active, finer soil particles. Once agricultural pollutants enter a water system, they lower water quality and can impose economic losses on water users. These offsite impacts can be significant. Recent research suggests that the economic offsite impacts of soil erosion may be of greater magnitude than the onsite productivity impacts (7).

If the runoff reaches the water body or stream, soil particles can be suspended in the water, or settle out as sediment, depending on the velocity of the waterflow and the size of the soil particles. In each case, water use can be affected.

Suspended soil particles affect the biologic nature of water systems by reducing the transmission of sunlight, raising surface water temperatures, and affecting the respiration and digestion of aquatic life. The effects on aquatic life, and the reduction in esthetic quality of recreation sites, can reduce the value of water for recreation uses. Suspended soil particles impose costs on water treatment facilities which must filter out the particles. Suspended soil particles can also damage moving parts in pumps and turbines.

Even when soil particles settle on the bottom, they can cause serious problems for aquatic life by covering food sources, hiding places, and nesting sites. Sedimentation can clog navigation channels and water conveyance systems like roadside ditches, reduce reservoir capacity, and damage recreation sites. In streambeds, sedimentation can lead to an increase in the frequency and severity of flooding by reducing channel capacity.

The nutrients and pesticides attached to soil particles, or dissolved in runoff, affect water quality in ways that can alter the suitability of water for many uses. The most far-reaching impact is eutrophication, excessive growth of algae and rooted vegetation caused by excessive nutrient runoff. Rooted plants can become a nuisance around marinas and shorelines. Floating algae blooms can restrict light penetration to surface waters and can affect the health, safety, and enjoyment of people using water for recreation. As the algae dies and decays, it uses oxygen from the surrounding water, lowering the dissolved oxygen level and altering the size and composition of commercial and recreational sport fisheries. Floating algae

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2/ Shortrun production impacts of gully erosion and wind erosion are not included in the analysis.

can clog intake pipes and filtration systems, increasing the cost of water treatment.

Pesticides create a broad array of impacts. Most notable are effects on aquatic wildlife. Very high concentrations will kill organisms outright. Lower concentrations, more commonly observed, can produce a variety of sublethal effects such as to lower resistance of fish, which makes them susceptible to other stresses. Herbicides can hinder photosynthesis in aquatic plants. Some pesticides can accumulate in animal tissue, and be passed along the food chain, where impacts on higher organisms can be particularly harmful. Pesticides can damage commercial and sport fisheries and make fish dangerous to eat.

Wind erosion produces offsite impacts that can be as dramatic as the Dust Bowl of the 1930's, but they have not received the attention given to the more widespread water erosion impacts (65). Damage can include higher maintenance of buildings and landscaping, pitting of automobile finishes and glass, greater wear on machinery parts, increased soiling and deterioration of retail inventories, costs of removing blown sand and dust from roads and ditches, and increased respiratory and eye disorders. Total damages from all sources of wind erosion in New Mexico were estimated at $500 million per year (19). Offsite damages from wind erosion depend on the extent and location of population centers relative to prevailing winds and wind erosion sources. Damage estimates for one area, thus, cannot easily be extrapolated to other areas, nor can the impact of wind erosion from cropland or other agricultural land be differentiated from wind erosion originating on nonagricultural land.

Offsite impacts of both water and wind erosion may be subject to "threshold" effects (72). A reduction in erosion may not produce proportional improvements in water or air quality unless they are quite large in relation to total loads. In economic terms, the costs of erosion control practices that result in only small reductions in erosion may produce few, if any, offsite benefits.

Wildlife Habitat

A third erosion-related problem deals with wildlife. Monocultural production and field consolidation have diminished habitat diversity in areas where agriculture once contributed to diversity. Soil conservation practices often enhance wildlife habitat. Field borders, windbreaks, hedgerows, streambank protection, and wildlife habitat management can increase habitat diversity. However, practices aimed at wildlife protection often divert land from row-crop production, thereby creating opportunity costs. Dollar benefits from improved wildlife habitat have not yet been calculated.

Overview of USDA Soil Conservation Programs and Expenditures

The U.S. Department of Agriculture has provided leadership in soil conservation since the midthirties, when a national awareness of the importance of proper use of farmland was aroused by Hugh Hammond Bennett and others. Today, eight USDA agencies are directly or indirectly involved in soil conservation (59).

In 1984, the Soil Conservation Service (SCS) accounted for 59 percent of USDA conservation expenditures, compared with 53 percent in 1979 (table 1). Overall, appropriations for conservation dropped 5 percent between 1979 and 1984 when adjusted for inflation; the largest percentage declines were in the Agricultural Stabilization and Conservation Service (ASCS) and in the Farmers Home Administration (FmHA).

A popular misconception is that the $1 billion spent by USDA on conservation programs is entirely devoted to soil erosion control. In fact, erosion control is only one of nine program objectives (table 2). However, a comparison of real expenditures over the past 5 years in these nine areas shows increasing attention being given to erosion control. Soil erosion control activities accounted for 42 percent of the department's conservation budget in 1984, compared with 30 percent in 1979 (table 2). This represents a significant redirection of conservation resources to priority problems established in USDA's national conservation program developed in response to the Soil and Water Resources Conservation Act (RCA).

Table 3 puts Federal expenditures into the context of total outlays for soil erosion control in 1983. Information on the measures or practices in place and newly implemented on farms in 1983 was obtained from the Farm Production Expenditures Survey conducted by USDA (66). Half ($493 million) of the total costs of soil conservation in 1983 were incurred by farm and ranch owners and operators. About 42 percent ($423 million) came from congressional appropriations through USDA conservation agencies. The remaining 9 percent ($92 million) represented contributions of State and county governments and local soil conservation and other resource districts.

In 1983, onfarm technical assistance, extension, and similar activities accounted for about $147 million or 14.5 percent of all soil conservation costs. Almost 90 percent of this ($131 million) was for technical assistance of the Soil Conservation Service, attributable specifically to erosion control. Extension Service and Forest Service contributed an additional $6.8 million and $200,000, respectively. Direct technical assistance for soil conservation provided by State and local agencies was valued at $9 million.

As of 1983, at least 17 States had enacted legislation authorizing cost sharing for soil conservation on private lands (62). It is difficult to relate appropriations for such purposes with soil conservation accomplished in a particular year. States and a few local governments contributed at least $24 million toward the cost of installing soil conservation improvements on farms, according to 1983 estimates. Some States also provide tax credits and other incentives to farmers for soil conservation, including credit for purchasing conservation tillage equipment.

Cost sharing programs of USDA accounted for most (88 percent) of the $201 million public cost of installing soil conservation practices on farms in 1983 (table 3). Private expenditures (nearly all from farm owners and operators) were $469 million and accounted for 70 percent of all installation expenditures. Some of the private investment may have been made to obtain shortrun production cost savings together with longrun soil productivity benefits.

Table 1--U.S. Department of Agriculture's total conservation appropriations for 1979, 1983, and 1984, by agency

Agency	Appropriations 1979	Appropriations 1983	Appropriations 1984	Share of total, 1984	Average annual change, 1979-1984	Average annual change, 1979-1984
	Millions of 1983 dollars 1/			Percent	Million dollars 1/	Percent
Agricultural Research Service	56.3	63.5	60.9	6	0.9	1.6
Agricultural Stabilization and Conservation Service	423.5	249.3	233.7	23	-37.9	-11.2
Cooperative State Research Service	21.4	28.0	26.2	3	1.0	4.2
Economic Research Service	3.5	2.9	7.3	1	2/ .3	6.5
Extension Service	15.2	15.9	15.3	2	--	.1
Farmers Home Administration	91.0	83.1	58.2	6	-6.6	-8.6
Forest Service	19.7	16.6	17.2	2	- .5	-2.6
Soil Conservation Service	724.1	720.6	613.4	59	-22.1	-3.3
Total conservation appropriations 3/	1,354.7	1,179.9	1,032.2	100	-64.5	-5.3

-- Less than $50,000 per year.
1/ Constant 1983 dollars.
2/ Increased rates for ERS based on $4.8 million for 1984 rather than $7.3 million, to allow for a broader interpretation of conservation-related economics research in 1984 than in 1979 or 1983 in RCA reports.
3/ Columns may not add to totals due to rounding.

Table 2--Distributions of appropriations among national resource concerns in USDA conservation programs, fiscal years 1979, 1983, and 1984

National resource concerns 1/	Appropriations			Share of total appropriations		Average annual change, 1979-1984	
	1979	1983	1984	1979	1984		
	Millions of 1983 dollars 2/			-- Percent --		Million dollars	Percent
Soil erosion control (NP)	405.3	423.0	432.2	30	42	5.4	1.3
Water conservation (NP)	146.4	129.2	106.5	11	10	-8.0	-6.2
Flood damage reduction (NP)	161.1	201.7	124.8	12	12	-7.3	-5.0
Pasture and range improvement (SL)	--	--	62.9	--	6	*	*
Water quality improvement (SL)	171.7	--	63.3	13	6	-21.7	-18.1
Community/urban conservation (SL)	170.6	--	45.0	13	4	-25.1	-23.4
Wildlife habitat improvement (SL)	42.3	--	28.0	3	3	-2.9	-2.9
Energy conservation (SL)	26.0	--	36.3	2	4	-2.1	-6.9
Organic waste management (SL)	18.0	--	10.7	1	1	-1.5	-9.9
Unallocable among concerns	--	320.4	25.2	--	2	*	*
Subtotal, distributed appropriations	1,141.4	1,074.3	934.9	84	91	-41.3	-3.9
Add: Undistributed programs 3/	213.3	105.6	97.3	16	9	-23.2	-17.0
Total, all conservation appropriations	1,354.7	1,179.9	1,032.2	100	100	-64.5	-5.3

-- = Not specified as a priority concern in 1979 or not individually estimated in allocations.
* = Changes not computed individually but reflected in total.
NP = National concerns prioritized at the national level in the National Conservation Program.
SL = National concerns to be prioritized at the State and local levels.

1/ Resource concerns as specified in the National Conservation Program (NCP) and prescribed for agency distribution of appropriations by programs or budget line items in annual RCA reports (60, pp. 30-32). A similar set of concerns was used to distribute 1979 appropriations in the initial (1980) RCA analysis (59, pp. 270-271).

2/ Constant 1983 dollars. Appropriations for 1979 from 1980 RCA analysis (59, pp. 270-271). Appropriations for 1983 and 1984 supplied by the Appraisal and Program Development Division of SCS as officially reported to it by all USDA conservation agencies.

3/ Loan programs of Farmers Home Administration (FmHA) and emergency conservation operations of ASCS and SCS are not distributed by resource concerns in this comparison; such distributions were reported for the initial RCA analysis but were not distributed among resource concerns in 1983 and 1984 RCA allocations.

Table 3--Private and public expenditures for soil erosion control in the United States, by functional activities and sources of funds, 1983

Soil conservation activities	Farm owners/ operators	State & local agencies	Federal agencies (USDA)	Total, all sources	Farm owners/ operators	State & local agencies	Federal agencies (USDA)
	Million dollars				Percent		
Onfarm technical assistance/extension	--	9.0	137.7	146.7	--	6	94
Onfarm installation expenditures	469.1	23.8	177.1	670.0	70	4	26
Conservation farming systems 1/	360.0	6.2	38.2	404.4	89	2	9
Soil conservation improvements 2/	109.1	17.6	103.1	229.8	47	8	45
Administrative costs	--	--	35.8	35.8			
Unassisted installation, by measures	316.7	--	--	316.7	100	--	--
Conservation farming systems	302.8	--	--	302.8	100	--	--
Soil conservation improvements	13.9	--	--	13.9	100	--	--
Assisted installation, by measures	152.4	23.8	177.1	353.3	43	7	50
Conservation farming systems	57.2	6.2	38.2	101.6	51	6	43
Soil conservation improvements	95.2	17.6	103.1	215.9	40	7	53
Administrative costs	--	--	35.8	35.8			
Maintenance and repair	23.7	--	--	23.7	100	--	--
Associated project conservation 3/	--	14.1	35.3	49.4	--	29	71
Associated research and development 3/	--	17.3	26.1	43.4	--	40	60
Associated data collection/analysis 3/	--	27.6	46.8	74.4	--	37	63
Total soil conservation expenditures	492.8	91.8	423.0	1,007.6	49	9	42

-- = Not available or not applicable.

1/ Includes such optionally continued practices as cover crop protection, contour farming, stripcropping, reduced and no-till cultivation, and soil-conserving crop rotations.

2/ Includes such enduring or permanent practices as vegetative cover establishment, grass waterways, terraces, diversions, grazing land protection, windbreak establishment, sediment retention structures, streambank protection, and tree planting to minimize erosion.

3/ Includes only activities related to monitoring or reducing soil erosion.

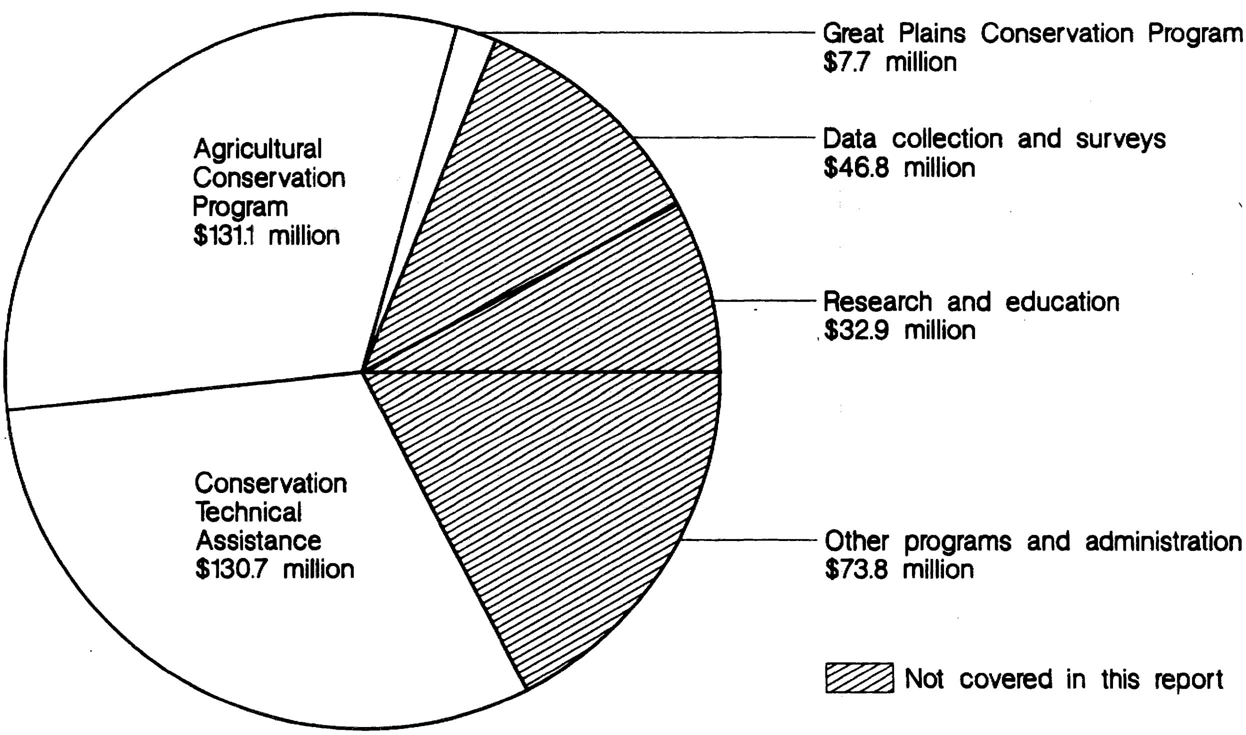
Public cost-sharing assistance for soil conservation on farms has gone mostly toward permanent vegetative cover and structural practices. These tend to be more costly per unit than conservation farming systems oriented toward annual management practices. Farmers who received cost-sharing in 1983 invested about $95 million in permanent improvements. This represented 62 percent of all private soil conservation investments made under cost-sharing arrangements.

Three Major Erosion Control Programs

This economic efficiency analysis is confined to three USDA erosion control programs, which accounted for almost two-thirds of the Department's soil conservation expenditures in 1983. The programs are Conservation Technical Assistance (CTA), the Agricultural Conservation Program (ACP), and the Great Plains Conservation Program (GPCP). Figure 2 shows the breakdown of USDA soil erosion control expenditures in 1983.

Figure 2

USDA erosion control expenditures in 1983, by major activity



The following program descriptions draw heavily on material in the 1980 RCA Appraisal (59), and particularly on a draft update of that report (18).

Conservation Technical Assistance Program

The Conservation Technical Assistance Program (CTA) was authorized by the Soil Conservation and Domestic Allotment Act of 1935 (44). The act called for a comprehensive program for the control and prevention of soil erosion to preserve natural resources, control floods, prevent the impairment of reservoirs, maintain the navigability of rivers and harbors, protect public health and public lands, and relieve unemployment.

The CTA is administered by the Soil Conservation Service. Most assistance is given through a nationwide system of about 3,000 special-purpose local governments, called soil conservation districts, soil and water conservation districts, natural resources districts, or conservation districts (CD's), established under State enabling legislation. USDA has a memorandum of understanding with each CD to assist in carrying out a long-term district conservation program. SCS has a supplemental memorandum to provide SCS personnel for resource planning, conservation, and development work on the basis of complementary CD and district-level SCS annual plans. A district-level SCS conservationist helps the district prepare its annual plan, which assigns priorities to particular lands. The SCS plan is based on CTA and other USDA conservation program priorities.

Assistance in preparing and applying individual farm conservation plans to carry out the CD and SCS plans is the main form of CTA assistance to farmers who are CD cooperators. This assistance includes interpreting existing soil surveys and conducting site-specific investigations of soil, plant, water, and other physical conditions to determine appropriate alternative systems of land use and land treatment. It also covers assistance in applying prescribed land treatment systems, where needed, including design, layout, and installation of conservation practices.

The SCS is authorized to conduct additional activities as components of the CTA program. SCS district personnel assist local and State agencies in planning rural development projects, and analyze soils to assist with facility siting. SCS State and district personnel help State and regional planning agencies with the continuing State and areawide nonpoint source pollution control planning conducted under Section 208 of the Clean Water Act (50).

SCS personnel are also assigned by the CD's to prepare the soil conservation standards used to implement State and local erosion and sediment control, nonpoint source pollution control, or wind erosion control laws and to assist in developing State coastal zone management plans. District personnel participate in reviews of development plans and building-permit applications for conformity to State and local erosion control, nonpoint source pollution control, coastal zone management, and flood plain regulations.

Agricultural Conservation Program

The Agricultural Conservation Program (ACP) was authorized by a 1936 amendment to the Soil Conservation and Domestic Allotment Act of 1935 (45). The legislative purposes of the act included improvement of farm income as well as soil and water conservation.

The objectives of the program that evolved were to "(1) restore and improve soil fertility; (2) minimize erosion caused by wind and water; and (3) conserve water on the land" (56). The program's general approach was to share with farmers and ranchers the costs of soil-building and soil- and water-conserving practices, including related wildlife-conserving practices.

The Agriculture and Consumer Protection Act of 1973 supplemented the original authority for ACP, among other things specifically authorizing long-term (3- to 10-year) cost-share agreements (51). More recent legislation limits cost-share assistance to preclude assistance that is primarily production oriented (52). The Energy Security Act in 1980 amended the original ACP authorizing legislation to include minimum tillage and other more energy efficient conservation practices (54).

A number of redirections in the ACP have been made in response to the National Program for Soil and Water Conservation (NCP) authorized under the Soil and Water Resources Conservation Act of 1977 (53). These include:

- Targeting. ACP funds are directed to critical resource problem areas designated by the Secretary on the basis of severity of priority resource problems identified by the NCP. Ten percent of ACP funds were earmarked for this purpose in fiscal years 1983 and 1984.

- Variable Cost Shares. Historically, a fixed cost-share level was used for all participants using a particular practice in the same county. In fiscal year 1985, ASCS provided, on a voluntary basis in 265 counties, an opportunity for an individual cost-share level based on soil loss reduction on specific land.

- Special Projects. Since fiscal 1982, certain ACP funds have been used to demonstrate local solutions to priority problems identified in the NCP: critical soil erosion, water conservation, and upstream flooding. Early special project emphasis was directed at conservation tillage systems. Special projects have more recently emphasized planting trees on critically eroding cropland.

- Acreage Conservation Reserve Project. At the national level, $20 million of fiscal year 1984 ACP funds were earmarked for 90-percent cost-sharing for the establishment of perennial grasses or trees on highly erodible land diverted under commodity programs.

The ACP is administered by State, county, and community-farmer Agricultural Stabilization and Conservation Committees under the general direction of the ASCS. Individual farmers file requests for cost-sharing assistance with the county committees. Except for certain group enterprises, no farmer can receive more than $3,500 of assistance annually, with the Federal cost-share rate being generally 50-75 percent.

Great Plains Conservation Program

The Great Plains Conservation Program (GPCP) was authorized by a 1956 amendment to Soil Conservation and Domestic Allotment Act of 1935 and the Agricultural Adjustment Act of 1938 (46). The objective of the program was to provide long-term technical assistance and cost-sharing assistance to farmers and ranchers in designated wind erosion counties. Assistance was provided through contracts with individuals based on plans to mitigate climatic hazards.

Amendments to the original act have dealt with the computational treatment of historic base acreage for administering commodity programs, broadening the program to nonfarm land and to lessees, and including practices and measures that enhance fish, wildlife, and recreation resources and control agricultural pollution (47, 48, 49).

The GPCP is administered by SCS. Conservation practices are chosen from a national list by State and county GPCP committees. The cost-share rate is set locally and varies according to the urgency of the need for the practice in the area. Farmers and ranchers apply for contracts based upon a plan of operation. When plans are approved, the producer contracts to install conservation practices on a 3- to 10-year schedule, with SCS paying 50-80 percent of the costs. By legislation, no new contracts may be entered after September 30, 1991.

EVOLVING CONCEPTS OF SOIL CONSERVATION PROGRAM EVALUATION*

Several previous evaluations of conservation programs have assessed individual programs and groups of programs. All of these studies have used physical measures of erosion as proxies for the onsite and offsite economic damages caused by erosion. Physical measures of erosion are imperfect indicators of economic damage (10).

Physical Erosion Measures

Physical erosion measures used over the past 50 years include estimates of gross erosion, erosion net of probable soil formation, and measures reflecting physical potential for erosion abstracted from current management. There are shortcomings and inconsistencies in all of these measures, some more severe in relation to offsite considerations and others limiting with respect to onsite problems.

Gross Erosion

Gross erosion indicates the volume of soil movement on the field, though not necessarily removed entirely from the site. More than 5 billion tons of soil were moved by water in 1982, about 35 percent from cropland alone (table 4).

*This section was prepared by Ralph Heimlich and Craig Osteen.

Table 4--Gross sheet, rill, and other erosion by source and farm production region, 1982

Region	Sheet and rill erosion				Other erosion (1977) 2/			Total 3/
	Cropland	Pasture	Range 1/	Forest 1/	Gullies, roads, and construction	Stream-bank	Quarries, pits, and mines	
	Million tons							
Northeast	65.5	6.2	0	18.5	24.7	23.4	46.5	184.8
Lake States	129.9	5.8	.1	11.4	16.2	10.8	7.0	181.3
Corn Belt	689.0	58.7	.7	54.9	36.1	75.2	54.9	969.7
Northern Plains	281.8	7.9	82.6	4.0	79.9	97.3	117.9	671.4
Appalachian	181.9	47.6	0	68.0	58.5	36.6	91.6	484.2
Southeast	94.0	5.0	.4	22.1	57.7	19.9	50.6	249.8
Delta States	116.3	11.5	.3	21.0	28.5	41.9	14.4	233.9
Southern Plains	112.4	20.4	144.6	16.4	86.9	91.2	18.3	490.2
Mountain	89.5	2.5	446.3	233.4	103.6	83.1	44.3	1,002.7
Pacific	66.6	3.3	185.9	277.5	51.2	73.4	11.2	669.1
Total 3/	1,827.9	168.9	861.1	727.2	543.4	552.9	456.8	5,137.3

1/ Erosion on Federal rangeland and forestland estimated by applying nonfederal erosion rates, by State, to Federal range and forest acreage.
2/ Estimated from 1977 Conservation Needs Inventory. 1982 estimates not available. Does not include wind erosion.
3/ Detail does not add to totals due to rounding.
Source: 1982 National Resources Inventory, except as noted.

Total tons of soil movement is not a useful measure of onsite productivity damages because the same amount of erosion could occur with low rates on many acres or with high rates on few acres. Gully erosion presents a different management problem than sheet and rill erosion because all of the productive soil is removed from the gullied area and gullies disrupt cultivation and harvesting operations, resulting in increased crop production costs.

Total water-caused erosion is a useful starting point for assessing offsite damages, because the sediment and chemicals contained in runoff from agricultural land can affect a wide variety of offsite, water-related activities. However, the relationship between soil movement and water quality is complex. The delivery of agricultural pollutants to waterways from agricultural land depends on many factors, including the size of the watershed, average slope, amount of ground cover, and stream density. Water quality in the receiving waterway depends not only on the agricultural pollutants discharged, but also on pollutants from other sources, as well as on the physical, chemical, and biological characteristics of the waterway. As for water users, the relationship between gross erosion and the demand for water or for water quality varies among uses and the intensity of use among watersheds. For these reasons, the use of gross erosion as a measure of erosion damages will lead to an inefficient allocation of resources.

A recent comparison of areas in the United States with potentially significant offsite damages and those with high rates of gross erosion yields further evidence that gross erosion is a poor measure of offsite erosion damage (37). Offsite damages will vary among regions depending on the kind and extent of impaired uses resulting from erosion, and on the relative importance of agricultural land as a source of pollutants in each region. For this comparison, areas were designated potential offsite damage areas if the following three conditions existed: (1) either instream (recreation) water use levels or water withdrawal levels were above the national mean; (2) excessive levels of at least one of three common agricultural pollutants (suspended solids, phosphorus, and nitrite-nitrate) were found in ambient water; and (3) agriculture contributed at least 50 percent of the pollutants which were found in excessive levels. Ninety-nine hydrologic regions covering the 48 contiguous States were examined. Fourteen regions were identified as potential offsite damage areas, but only seven of those had high levels of erosion. That is, the gross erosion criterion identified only half of the regions where offsite damages were significant.

Erosion Rates and Tolerance Values

Net erosion rates per acre are a better measure of onsite damages than are gross erosion rates. Soil is a renewable resource that is constantly forming. Low erosion rates may be offset by soil formation, in which case no loss in productivity will result.

Tolerable soil loss (T-value) is defined as the "maximum rate of annual soil erosion that may occur and still permit a high level of crop productivity to be obtained economically and indefinitely" (71). T-values, established in 1961 and 1962 based on rates of topsoil formation, range from 2-5 tons per acre per year (TAY) (26). Erosion rates in relation to T-values on cropland are shown in table 5.

Table 5--Annual sheet, rill, and wind erosion on cropland, 1982

Annual erosion rate	Sheet and rill erosion				Wind erosion			
	Cropland		Erosion		Cropland		Erosion	
Tons per acre	Million acres	Cumulative percent	Million tons	Cumulative percent	Million acres	Cumulative percent	Million tons	Cumulative percent
Less than T	315.1	74.8	505.7	27.4	353.6	83.9	211.7	16.9
T to T+1	21.2	79.8	96.8	32.7	9.8	86.2	48.0	20.8
T+1 to T+2	14.8	83.3	83.1	37.2	8.5	88.2	50.8	24.8
T+2 to T+3	11.1	85.9	73.1	41.2	6.4	89.8	45.5	28.5
T+3 to T+4	8.6	88.0	65.0	44.7	5.4	91.0	43.6	32.0
T+4 to T+5	6.5	89.5	56.2	47.7	4.4	92.1	40.3	35.2
T+5 to T+10	18.6	93.9	208.1	59.0	14.2	95.5	165.6	48.5
T+10 to T+15	9.0	96.1	147.1	67.0	6.4	97.0	108.6	57.2
T+15 to T+20	4.9	97.2	106.2	72.8	3.6	97.8	78.6	63.4
Greater than T+20	11.6	100.0	502.1	100.0	9.1	100.0	456.5	100.0
Total	421.4		1,843.4		421.4		1,249.2	

T = Tolerable soil loss, generally 2-5 tons per acre per year. See text.
Source: 1982 National Resources Inventory.

Dissatisfaction with existing T-values has been voiced recently. Critics cite the lack of a scientific basis for such values and the lack of economic criteria used to derive them (8, 9, 40). A proposed alternative would base T-values explicitly on the expected productivity loss for each soil, as estimated by recent erosion/productivity models. Such an approach, specifying a permissible 5-percent cumulative decline in productivity over a 100-year planning horizon, has been applied to Dakota County, Minnesota (33). The observed range in tolerance values based directly on productivity changes is from a low of 1.3 TAY to a high of 40 TAY. Based on this limited evidence, a wider range of variation in tolerable soil losses appears to exist between soils, hence, greater differences in the erosion productivity relationship, than is reflected in currently assigned T-values.

Soil loss tolerance goals, like gross erosion criteria, have limited relevance for offsite damage estimation. Water quality is impaired because of the total amount of sediment and chemicals delivered to the water body, regardless of their source. Relatively low erosion rates on many acres in a watershed can be as damaging as high erosion rates on a few acres, if the total pollutant load delivered to the stream is equal.

Erosion Potential

The disadvantage of analyzing onsite problems by erosion rate classes is that they fail to separate erosion due to physical erodibility from erosion due to management. A traditional approach to controlling for the physical features of cropland involves classifying soils according to erosion hazard. USDA's land capability class and subclass system identified erosion hazards with subclass e, and the degree of limitation with classes ranging from I (few limitations) to VII (very severe limitations). The drawback to this method is that subclass e identifies only those soils for which erosion is the dominant limitation. Soils falling into other subclasses (for example, cold, wet, or stony soils) can also have erosion problems. There are also wide variances in erosion levels within the same capability class and subclass.

A classification based on the Universal Soil Loss Equation (USLE) was recently developed to control for management (71). The classification system separates the physical erosion potential of the land from the management applied to the land, in relation to established soil loss tolerance goals (5). Four classes were derived in this system. Cropland is termed "nonerodible" if it has physical characteristics that allow it to be intensively cropped without conservation practices and still not erode above tolerable levels. At the other extreme is land so steep that it cannot be managed for intensive row crop production, even with conservation practices, without eroding above tolerance. This land is termed "highly erodible." According to this classification, almost 40 percent of cropland in production in 1982 was nonerodible and had sheet and rill erosion below 5 TAY (table 6). Another 39 percent was moderately erodible, but was managed with appropriate crop rotations and conservation practices to keep sheet and rill erosion below the 5-ton goal utilized in this analysis. A modification of this system has been recently proposed by a USDA interagency work group on fragile soils (25).

Table 6--Cropland by soil erosion class and gross sheet and rill erosion rate, United States, 1982

Annual erosion rate	Total	Nonerodible	Moderately erodible: Managed below 5 TAY	Moderately erodible: Managed above 5 TAY	Highly erodible
Tons per acre			1,000 acres		
Less than 5	328,762	165,136	163,626	--	--
5 to 13	65,014	--	--	54,988	10,026
14 to 24	14,681	--	--	5,872	8,809
25 or more	10,990	--	--	51	10,860
Total 1/	419,447	165,136	163,626	60,945	29,740
			Percent		
Less than 5	78.4	39.4	39.0	--	--
5 to 13	15.5	--	--	13.1	2.4
14 to 24	3.5	--	--	1.4	2.1
25 or more	2.6	--	--	*	2.6
Total	100.0	39.4	39.0	14.5	7.1

-- = Not applicable.
* = less than 0.1 percent.
1/ Detail does not add to published totals due to recording 1.9 million acres of pastureland subsequent to release of the 1982 NRI tape.
Source: 1982 National Resources Inventory.

While the erosion potential measure is a more useful physically based measure of damages than those described previously, it too falls short of identifying economic damages. The soil loss goal used, be it 5 TAY or the actual T-value for the soil, does not reflect the economic benefits from reducing erosion's effect on productivity. Incorporation of management in the form of most and least erosive cropping and conservation systems only crudely reflects the costs of reducing erosion to levels where productivity is not impaired. Explicit treatment of productivity benefits and erosion control costs is needed to make an economic assessment of current erosion-caused problems.

Earlier Evaluations of Program Effectiveness

In this section, we discuss previous evaluations of the three USDA programs, the effects they have had on conservation programs, and their implications for the study reported here.

1974 GPCP Evaluation

In a 1974 evaluation, USDA estimated that the GPCP's cost-sharing program achieved 56 percent technical efficiency in reducing wind and water erosion (61). (The voluntary nature of the program would make it difficult to achieve 100 percent efficiency.) The evaluators stated that the program could be made more efficient by reallocating funds to more cost-effective erosion control practices, identified the most cost-effective practices, and suggested that cost-shares be based on the tons of erosion reduced, not the cost of the practice. The evaluation was based on the program's practices, cost per ton of erosion control, and expected changes in erosion caused by different allocations of cost-share funds.

General Accounting Office Evaluations of Three Major Programs

A 1977 GAO evaluation of the ACP, CTA, and GPCP did not criticize USDA's conservation goals but stated that the programs were less effective than they could have been in establishing enduring conservation practices and reducing erosion to tolerable levels (68). The study's emphasis was on changes in program management to increase efficiency in conserving soil. The evaluators visited 283 farms in 60 counties in eight States, and found that 84 percent of the participating farms had erosion rates in excess of 5 TAY, which was not significantly less than nearby farms who did not participate.

GAO criticized the CTA program for being too passive: The farmers served were those seeking assistance, not necessarily those with severe erosion problems. The ACP program was singled out for spending cost-share funds on production-oriented practices with minimal erosion control benefits, such as irrigation and drainage. The GPCP was criticized for reasons similar to those for the CTA and ACP. GAO recommended that resources be directed to high-priority problems first.

In 1983, GAO made a second evaluation of the ACP, CTA, and GPCP, building upon the 1977 GAO audit described above. GAO argued that the goal of soil conservation programs should be to minimize offsite and onsite damages rather than reduce the amount of erosion. Due to the lack of data to quantify harmful effects of erosion, GAO believed the approach of minimizing erosion and targeting critical problem areas, as outlined in the 1982 RCA program (62), may be the best alternative. The evaluators recommended that USDA collect information and conduct research on soil erosion damages. The study also questioned the validity of T-values as a goal for reducing erosion and suggested that USDA investigate the importance of topsoil depth, productivity, and subsoil impacts in setting guidelines.

GAO also criticized all three programs for measuring performance by activity levels, such as the number of practices installed or farms visited, rather than conservation performance. It said USDA's criteria for allocating resources were only indirectly related to the severity of erosion problems and their harmful impacts, although GAO acknowledged recent USDA attempts to target funds to critical problem areas.

1975-78 ACP Evaluation

Another USDA evaluation concluded that about 50 percent of the ACP assistance was applied to land eroding at less than 5 tons per acre (57). The study also found that the cost per ton of erosion reduction was dramatically lower for conservation practices applied to lands with high erosion rates. For example, the cost of practices on land eroding at less than 5 tons per acre was $14.87 per ton versus $0.62 per ton on land eroding at 15-30 tons. Stripcropping, conservation tillage, critical area treatment, and competitive shrub control were found to be the most cost-effective practices, depending upon the pretreatment erosion rate. The evaluators concluded that effectively targeting erosion control funds to locations with the highest potential for erosion reduction could more than triple the erosion reduced by the program. Funding more cost effective practices would also help to bring further improvements. The study did not address the appropriateness of program goals or the value of the program's accomplishments.

1983 CTA Evaluation

The Soil Conservation Service analyzed the cost effectiveness of direct conservation technical assistance to landowners in 1983 and progress toward achieving USDA's national conservation program objectives (64).

The study found that erosion reductions per acre for all land uses were greater in the targeted areas than nationwide, 6.0 and 4.4 tons per acre, respectively. In addition, it was found that the erosion reductions and acres treated per CTA hour were less in the targeted areas, indicating more intensive effort is needed to develop solutions for land with more severe erosion problems. The evaluators also noted that the cost of erosion reduction on all land was $1.71 per ton, with landowners bearing four-fifths of the costs.

About 40 percent of the land receiving direct assistance was found to be eroding at less than T. The evaluators argued that program performance could be improved by spending less time on acres eroding at less than T, but noted that erosion could increase on such acres as a result if farmers abandoned conservation practices on these acres. They also concluded that coordinating technical and financial assistance on priority problems could improve program efficiency. The study did not question the appropriateness of program goals or estimate the value of program accomplishments.

Impacts of Evaluations on Conservation Programs

The 1977 GAO audit, the 1974 GPCP evaluation, and the 1975-78 ACP evaluation all identified ways to increase the amount of soil conserved with available resources:

- o Reduce financial assistance for practices that are oriented to production and conserve little soil;
- o Reduce financial assistance for conservation practices that are not the most cost effective;

- o Shift technical and financial assistance from areas with minor erosion problems to areas with severe problems;
- o Concentrate conservation planning on the most severe problems found on individual farms and give less attention to the details of comprehensive, whole farm plans.

USDA changed some aspects of conservation programs in response to these suggestions, particularly those of the 1977 GAO audit. SCS changed farm planning procedures, under the CTA, to place less emphasis on the details of the planning document and more on applied conservation (2, 60). SCS developed a new manual to streamline planning procedures, changed progress reporting to stress the performance of practices rather than the practices applied, and conducted an evaluation of the CTA, noted above. For the GPCP, SCS required State offices to develop priorities tailored to the State's resource needs; SCS also planned a new evaluation of the program. ASCS changed ACP procedures emphasizing enduring practices in 1978, eliminated production-oriented practices in 1979, and completed the ACP evaluation in 1981.

The 1983 GAO audit recommendation that the major program goal should be to reduce the value of erosion damages, both offsite and onsite, rather than to reduce total erosion in excess of T-value, has strong implications for modifying conservation program priorities and resource allocations. First, such a goal implies that soil productivity should not be the exclusive priority for conservation programs, particularly if offsite damages exceed losses in productivity. Second, the value of the potential crop production loss, rather than the rate of erosion, is the appropriate criterion for determining the most urgent erosion-caused productivity impacts. The GAO audit thus implied that a more complete economic analysis of the impacts of erosion control measures would help to increase the efficiency of conservation programs, beyond what is possible by analyzing program cost-effectiveness.

Those earlier evaluations used physical measures or cost effectiveness analysis to determine how a given allocation of resources should be allocated to maximize erosion reduction. Cost effectiveness analysis, which measures program outputs in physical units, such as tons of soil saved per dollar of expenditures, was used to make recommendations to the Department in the 1983 CTA Evaluation. It was implicitly assumed that the eroded soil had the same value in all situations. An inch of soil off a thin soil in Missouri was worth the same as an inch of soil from the deep loess soils of Iowa. A ton of soil affecting a salmon fishery in Maine was assumed to inflict the same damages to society as a ton of soil eroding into a farm pond. Analysts were limited to cost effectiveness analysis because there were no data or procedures to quantify the economic benefits of soil erosion control.

Physical measures, and even cost effectiveness, to assess conservation programs do not provide the full array of information needed to adequately weigh the economic merits of program options to maximize program performance. When alternative program options that result in diverse physical outputs are considered, the outcomes must be compared by common measurement criteria. Benefit-cost analysis can provide such a common measurement basis.

Benefit-cost analysis is a useful tool to evaluate the efficiency of resource use. In benefit-cost analysis, the primary benefits and costs of program options are compared. A ratio greater than one implies a net gain to society from allocating additional resources into that program option. Comparison of benefit-cost ratios of alternative program options provides a means by which public agencies can determine which options yield the largest social return. Shifting resources from program options with low benefit-cost ratios to options with higher benefit-cost ratios results in a more efficient program. The ratios, however, do not indicate the magnitude of benefits that would be gained by reallocating program funds from low to high benefit-cost ratio options.

Benefit-cost analysis is a tool for improving the efficiency of resource use both within a program purpose and between program purposes. But efficiency is only one criterion on which decisions are based. Other objectives may also be important to policymakers. These include equity considerations (income distribution), intergeneration effects, and risk aversion. Therefore, benefit-cost analysis should be considered as a framework and a set of procedures to help organize available information. Policymakers and program managers have to weigh the importance of economic versus noneconomic objectives when making program choices.

Recent advances in knowledge have now given us the data necessary to undertake a first attempt to examine major soil conservation programs through benefit-cost analysis (28, 70). This study estimates the value of ACP, CTA and GPCP program accomplishments in terms of both onsite and offsite damages prevented, as recommended by the 1983 GAO audit. We examined the efficiency of public and private expenditures for conservation activities that were carried out in 1983 under these programs, using the same procedures and data bases. Emphasis was placed on analyzing erosion control benefits and costs on cropland eroding at different rates.

APPRAISAL OF EROSION CONTROL PROGRAMS*

New procedures were used to calculate productivity benefits, offsite benefits, and program costs related to erosion control practices applied to cropland. 3/ Productivity and offsite benefits were both estimated from erosion reductions obtained from federally subsidized conservation practices. These erosion reduction data were obtained from a national sample of observations from the USDA Conservation Reporting and Evaluation System (CRES) for 1983. Productivity benefits per ton of erosion reduction were obtained from a combination of variables, including changes in crop yield per ton of soil erosion from the Erosion Productivity Impact Calculator (EPIC) model developed jointly by the Agricultural Research Service, the Economic Research Service, and the Soil Conservation Service. Offsite benefits per ton of erosion reduction were primarily constructed from damage estimates compiled recently by the Conservation Foundation (7).

3/ These procedures are described in detail in the appendix.
* Evaluations and implications presented in this section were made by Linda Lee based on empirical analyses conducted by Daniel Colacicco, Marc Ribaudo, and Alexander Barbarika.

Data were not available to estimate reductions in offsite damages resulting from wind erosion control.

Estimates of costs, both public and private, of erosion control expenditures were obtained from the 1983 CRES sample. In the case of conservation tillage, the difference in net returns between conventional and conservation tillage were also obtained from modified budget data obtained from the Center for Agriculture and Rural Development (CARD), Iowa State University. Data were not available to estimate the shortrun net income (production) benefits that may be a joint product of some soil conservation practices. In particular, data were lacking to estimate (1) shortrun crop losses due to wind erosion; (2) the effect of gully erosion on annual crop production costs; (3) crop yield gains due to soil moisture management in semi-arid areas; (4) shortrun production costs of conservation practices due to additional labor and fuel costs; and (5) shortrun opportunity costs arising from less intensive conservation cropping systems. 4/ With the exception of conservation tillage, our analysis is limited to comparing the cost of erosion control measures with the long-term productivity and offsite damage reduction benefits.

Benefits and costs were calculated by determining the present value of the stream of benefits and costs that were attributable to the erosion reduction that occurred over the lifespan of individual conservation practices. Productivity benefits of soil conservation measures were discounted over an infinite planning horizon. Offsite benefits were discounted over the life of the conservation practice, assuming that offsite benefits are zero beyond the life of the practice. The maximum lifespan of any conservation measure included in the analysis was 20 years. A 4-percent discount rate was used to determine present values. All calculations were carried out in constant 1983 dollars.

Erosion Control Benefits and Costs

In 1983 about 16.5 million acres of cropland were treated under the programs analyzed in this report. About 385 million tons of erosion reduction occurred over the life of conservation practices implemented under these programs. Productivity benefits were valued at $99 million. Offsite benefits were valued at $175 million, or about two-thirds of total program benefits. The total private and public costs associated with these erosion reductions were about $419 million. The mid-level benefit-cost ratio associated with these estimates is 0.7, based on our data and assumptions. However, because the offsite benefits span a possible range of $104-$261 million, and conservation tillage costs attributable to erosion control vary, the benefit-cost ratios could range from 0.3-0.9.

Sensitivity of Analysis to Alternative Assumptions

The uncertainty about offsite benefit data and conservation tillage costs and returns deserves particular attention. The offsite benefit estimates rely heavily on national damage estimates developed by the Conservation

4/ A more complete discussion of the potential shortrun production costs and benefits of erosion control measures is presented in the appendix.

Foundation (see appendix). Due to limited sources of information available and the types of assumptions that had to be made in that study, the offsite damage estimates are subject to considerable uncertainty. Offsite benefit ranges are presented in appendix table 11. The best estimates are bounded by a set of high and low estimates.

Uncertainty about conservation tillage costs occurs because data on the CRES form are not based on a consistent definition of costs. Also, the change in annual production costs and returns associated with a shift to conservation tillage was not revealed in the CRES data. Because of these limitations and the importance of conservation tillage as an erosion reduction practice, farm budget data were also used to estimate conservation tillage costs. With this alternative procedure, the annual cost of shifting to conservation tillage is defined as the difference in annual net returns between conventional and conservation tillage. Estimates of these differences in net returns were developed from modified budgets obtained from the Center for Agriculture and Rural Development (CARD), Iowa State University. Cost estimates based on the CARD budget data are generally lower than those obtained from CRES.

Because of these data uncertainties, we present a range of benefit-cost ratios from 0.3-0.9 (table 7). The use of the most conservative estimates--the lowest offsite benefits and CRES conservation tillage costs--leads to an overall benefit-cost ratio of 0.3. Using the highest offsite benefits and the lower CARD conservation tillage costs leads to an overall benefit-cost ratio of 0.9. The mid-level estimate, 0.7, is based on the use of CARD conservation tillage costs and medium offsite benefits. Throughout the remainder of the discussion, unless otherwise specified, the mid-level estimate is referred to in the text.

Table 7--Alternative conservation program social benefit-cost ratios for cropland, 1983

Benefit-cost category	Offsite benefits 1/	Conservation tillage costs 2/	Total costs	Total benefits	Social benefit-cost ratio
			Million dollars		Ratio
Low	Low	CRES	614.9	203.6	0.3
Mid-level	Medium	CARD budgets	419.4	274.6	.7
High	High	CARD budgets	419.4	359.9	.9

1/ Three levels of offsite benefits represent ranges described in the appendix.

2/ Conservation tillage costs were derived alternatively from the Conservation Reporting and Evaluation System (CRES), USDA, and budgets derived by the Center for Agriculture and Rural Development (CARD) at Iowa State University.

Additional uncertainty affecting the benefits and costs stems from the lack of information about the full array of economic effects of conservation practices. Data were not available to estimate all of the shortrun production benefits and costs. As discussed earlier, reduction of crop losses due to wind erosion control, production cost-savings due to gully control and gains in crop yields due to soil moisture management were omitted from the analysis. To the extent that conservation practices have joint conservation benefits and shortrun production gains, their costs attributed to conservation (soil productivity and offsite benefits) may be overstated. On the other hand, some conservation practices, such as contour farming, stripcropping, terraces, permanent vegetative cover and conservation cropping systems are likely to have negative shortrun production effects due to additional labor and fuel costs or to opportunity costs of less intensive cropping systems. We also lacked data about the nature and magnitude of offsite damages due to wind erosion from cropland. The composite effect of these unknown benefits and costs could result in underestimating the benefit-cost ratio.

Analysis by Erosion Rates

The economic return to conservation investments is higher for cropland eroding at higher rates (table 8). The mid-level benefit-cost ratio for cropland eroding at or less than 2 tons per acre is only 0.1. The mid-level benefit-cost ratio exceeds 1.0 at about 15 tons per acre and reaches 1.5 at more than 20 tons per acre. In some situations, of course, the productivity and offsite benefits for specific soils eroding at less than 15 tons per acre would have benefits exceeding costs if the productivity loss per ton of erosion for that specific soil is particularly high (e.g., a shallow soil) or the offsite damages in the local area are high. Likewise, some soils with annual prepractice erosion rates exceeding 15 tons would have conservation costs exceeding benefits if the productivity loss and offsite damages per ton of erosion are low.

Like the 1977 GAO evaluation, the 1975-78 ACP evaluation, and the 1983 CTA evaluation, our analysis indicates that a significant portion of land treated under the various conservation programs erodes at a relatively low rate even without any conservation treatments or practices. Of the nearly 17 million acres of cropland treated by the various programs, about 40 percent of these acres had erosion rates of 5 tons per acre or less. Conservation treatments on these lands reduced soil erosion by only 8 percent. At the other end of the erosion rate scale, 10 percent of the cropland treated was eroding at more than 20 tons per acre. Conservation treatments on these lands reduced erosion by 38 percent.

Some of the conservation measures applied to land eroding at less than 5 tons per acre may have been preventive maintenance treatments. Such treatments could be necessary to maintain low erosion rates on land that is highly erodible without showing any significant productivity or offsite damage benefits. However, to the extent conservation treatments are being applied to land with low erosion rates and low soil productivity loss, this is an important area for program managers to explore for improved efficiency.

Table 8--Acres treated, erosion reductions, benefits and costs of conservation programs on cropland by prepractice erosion rates, 1983

Erosion rate	Acres treated	Erosion reduction over time 1/	Total social cost	Benefits			Benefit-cost ratio 3/		
				Productivity	Offsite 2/	Total	Low	Medium	High
Tons per acre	Million acres	Million tons	--------- Million dollars ---------				----- Ratio -----		
0-2	2.2	3.2	41.9	1.9	0.7	2.7	0	0.1	0.1
2.1 - 5	4.5	26.8	79.4	8.7	13.5	22.3	.1	.3	.4
5.1 - 10	4.7	76.1	102.5	20.7	35.6	56.3	.3	.6	.7
10.1 - 15	2.2	65.2	68.4	17.2	27.8	45.0	.3	.7	.8
15.1 - 20	1.1	56.9	33.4	12.6	24.0	36.7	.6	1.1	1.4
Greater than 20	1.7	148.0	59.3	35.3	54.9	90.2	.8	1.5	2.0
Other 4/	*	8.7	34.6	2.6	18.8	21.4	--	--	--
Total 5/	16.5	384.9	419.4	99.2	175.4	274.6	.3	.7	.9

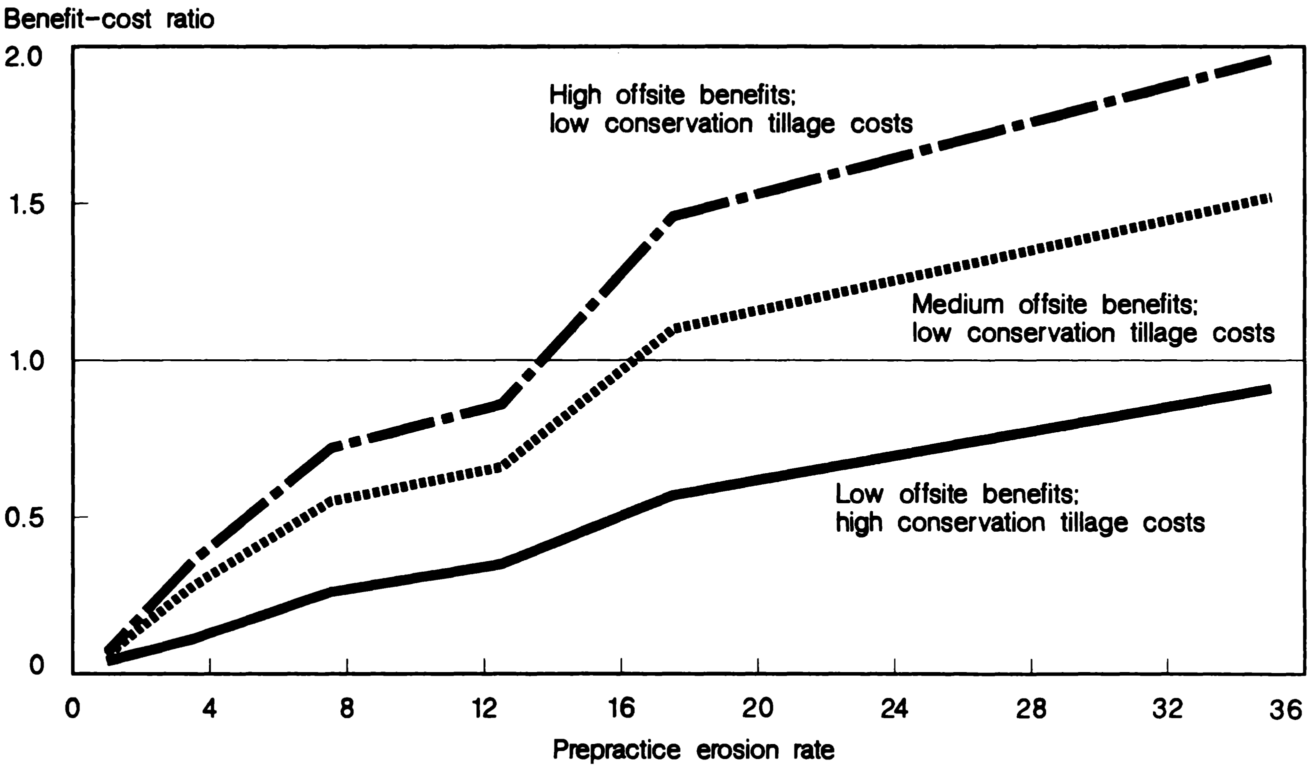
* = Less than 50,000 acres.
-- = Not calculated. See footnote 4.
1/ Includes sheet and rill, wind, and other erosion over the lifespan of the conservation practice adopted (1-20 years).
2/ Offsite benefits are calculated with zero benefits for wind erosion reduction.
3/ "Low" means CRES conservation tillage costs and low offsite benefit assumptions.
"Medium" means CARD conservation tillage costs and medium offsite benefit assumptions.
"High" means CARD conservation tillage costs and high offsite benefit assumptions.
4/ Other erosion includes gullies. Productivity losses are assigned to gully erosion as they are to sheet and rill, and wind erosion because no shortrun production impacts have yet been calculated. No overall benefit-cost ratio is calculated. Where gully erosion occurs simultaneously with other forms of erosion, it could not be separated and is included in the other categories.
5/ Columns may not add to totals because of rounding.

Figure 3 illustrates the sensitivity of the estimated benefit-cost ratio to the assumptions about offsite benefits and conservation tillage costs. The benefit-cost ratio, however, is less than 1.0 for soils with prepractice erosion rates below about 14 tons per acre under all assumptions regarding uncertainty of the benefits and costs.

Both productivity and offsite benefits are greater at higher erosion rates. This is because the total tons of soil erosion increase and offsite effects, in particular, are directly related to tons of soil erosion. Productivity benefits, however, do not vary in direct proportion to tons of erosion due to the variation among soils in the depth of topsoil and other soil characteristics. For any given soil, however, productivity losses and offsite damages both increase as the erosion rate increases. This analysis indicates, as did the 1975-78 ACP evaluation, that costs per ton of erosion reduction are much higher at lower erosion rates. On cropland eroding at 2 tons per acre or less, the cost is approximately $13 per ton to reduce soil erosion, compared with about 40 cents per ton on land eroding at over 20 tons per acre. Again, these costs are based on mid-level estimates.

Figure 3

Erosion control benefit-cost ratios under alternative assumptions



One implication of table 8 is that the economic efficiency of soil conservation investments could be increased by redirecting program funds to cropland with higher erosion rates. On cropland with erosion rates greater than 15 tons per acre, the benefit-cost ratio was over 1.0. However, approximately 30 percent of the program funds and about 40 percent of the acres treated in 1983 involved cropland where the benefits are low because erosion rates were less than 5 tons per acre before treatment. Current conservation programs are treating only about 6 million acres a year out of the 97 million acres of U.S. cropland eroding at more than 2T. 5/

An alternative way to express prepractice erosion rates is in soil loss tolerance (T-value) intervals. T-value intervals may be more precise when T is actually below 5 tons per acre. Where T exceeds 5 tons per acre, T-value intervals can give less information than gross erosion rates. Table 9 expresses prepractice erosion rates in T-value intervals. The implications about erosion rates and benefit-cost ratios that can be drawn from tables 8 and 9 are very similar.

Analysis by Program

In 1983, nearly 17 million acres of cropland were treated under the three programs leading to about 385 million tons of erosion reduction over the lifespan of the conservation practices adopted. The CTA only program treated nearly three-fourths of the total acres and accounted for about one-half of the estimated total tons of erosion reduction over time by all the programs. The CTA program with ACP cost-share funds treated a smaller number of acres, but the reduction in soil erosion over the life of the practices adopted is 44 percent of the total reduction in soil erosion. The other programs, ACP cost-share only and the GPCP, together constitute about 4 percent of the total acres treated in 1983 and a similar share of reduced soil erosion.

The costs per ton of soil saved vary by program. The ACP cost-share only and CTA with ACP cost-share have the highest costs, $1.47 and $1.18 per ton, respectively. These programs may be implementing more costly conservation measures.

Table 10 also compares the onsite productivity and offsite benefits of conservation programs with the costs of implementation. The benefit-cost ratios do not differ greatly among programs. The GPCP program had a slightly lower ratio than other programs. However, lower confidence can be placed in this estimate because of the relatively small number of acres treated under this program and the small sample size.

Public and Private Benefit-Cost Ratios

Total private and public conservation costs associated with ACP, CTA, and GPCP programs were approximately $419 million in 1983, of which approximately $200 million, or half, represents public funds (table 11). Federal expenditures constitute over 90 percent of the public funds. The

5/ Unpublished data from the 1982 National Resources Inventory conducted by the Soil Conservation Service, USDA.

Table 9--Acres treated, erosion reductions, benefits, and costs of conservation programs on cropland by prepractice erosion rates, 1983

Erosion rate in relation to T-values	Acres treated	Erosion reduction over time 1/	Total social cost	Benefits: Productivity	Benefits: Offsite 2/	Benefits: Total	Benefit-cost ratio 3/: Low	Benefit-cost ratio 3/: Medium	Benefit-cost ratio 3/: High
	Million acres	Million tons	Million dollars				Ratio		
Less than T	6.2	25.9	107.3	9.0	11.5	20.5	0.1	0.2	0.2
T-2T	4.5	61.9	96.0	16.2	30.0	46.2	.2	.5	.6
2T-4T	3.7	120.9	106.1	30.2	50.5	80.7	.4	.8	1.0
Greater than 4T	2.1	167.5	75.4	41.2	64.5	105.8	.8	1.4	1.8
Other 4/	*	8.7	34.6	2.6	18.8	21.4	--	--	--
Total 5/	16.5	384.9	419.4	99.2	175.4	274.5	.3	.7	.9

* = Less than 50,000 acres.
-- = Not calculated. See footnote 4.
1/ Includes sheet and rill, wind, and other erosion.
2/ Offsite benefits are calculated with zero benefits for wind erosion reduction.
3/ "Low" means CRES conservation tillage costs and low offsite benefit assumptions.
"Medium" means CARD conservation tillage costs and medium offsite benefit assumptions.
"High" means CARD conservation tillage costs and high offsite benefit assumptions.
4/ Other erosion includes gullies. Productivity losses are assigned to gully erosion as they are to sheet and rill, and wind erosion because no shortrun production impacts have yet been calculated. No overall benefit-cost ratio is calculated. Where gully erosion occurs simultaneously with other forms of erosion, it could not be separated and is included in the other categories.
5/ Columns may not add to totals because of rounding.

Table 10--Acres treated, erosion reductions, benefits, and costs of conservation programs on cropland, 1983

Conservation program	Acres treated	Erosion reduction over time 1/	Total social cost	Benefits			Benefit-cost ratio 3/		
				Productivity	Offsite 2/	Total	Low	Medium	High
	Million acres	Million tons	---------- Million dollars ----------				----- Ratio -----		
CTA with ACP cost-share 4/	3.7	170.7	202.3	41.4	73.5	114.8	0.3	0.6	0.7
CTA only 5/	12.1	198.9	198.2	53.1	93.9	147.0	.4	.7	1.0
ACP cost-share only 6/	.4	8.5	12.4	2.9	6.7	9.6	.4	.8	1.0
GPCP 7/	.2	6.9	6.5	1.8	1.3	3.1	.3	.5	.6
Total 8/	16.5	384.9	419.4	99.2	175.4	274.6	.3	.7	.9

1/ Includes sheet and rill, wind, and other erosion.
2/ Offsite benefits are calculated with zero benefits for wind erosion reduction.
3/ "Low" means CRES conservation tillage costs and low offsite benefit assumptions.
"Medium" means CARD conservation tillage costs and medium offsite benefit assumptions.
"High" means CARD conservation tillage costs and high offsite benefit assumptions.
4/ Conservation Technical Assistance with Agricultural Conservation Program cost-share.
5/ Conservation Technical Assistance only.
6/ Agricultural Conservation Program cost-share only.
7/ Great Plains Conservation Program.
8/ Columns may not add to totals because of rounding.

Table 11--Costs of conservation measures for erosion control on cropland, 1983

Conservation program	Private costs			Public costs						Total
	Install, operate, and maintain 1/	Technical assistance	Total	Cost-share Federal	Cost-share Non-federal	Technical assistance Federal	Technical assistance Non-federal	Total Federal	Total Non-federal	
				1,000 dollars						
CTA with ACP cost-share 2/	53,879	476	54,355	80,104	1,068	60,607	6,143	140,711	7,211	202,277
CTA only 3/	154,724	857	155,581	0	5,013	35,107	2,524	35,107	7,537	198,225
ACP cost-share only 4/	5,078	1	5,079	7,166	0	190	1	7,356	1	12,436
GPCP 5/	3,360	38	3,398	1,274	21	1,721	63	2,995	84	6,477
Total	217,042	1,372	218,414	88,544	6,103	97,624	8,731	186,168	14,833	419,415

1/ Includes conservation tillage costs based on CARD budget data.
2/ Conservation Technical Assistance with Agricultural Conservation Program cost-share.
3/ Conservation Technical Assistance only.
4/ Agricultural Conservation Program cost-share only.
5/ Great Plains Conservation Program.

CTA with ACP cost-share combination accounted for 48 percent of the total erosion control expenditures on cropland. The CTA program by itself represented another 47 percent of total expenditures. About 5 percent of the cropland erosion control costs were incurred for ACP only and GPCP.

If one assumes that the private farmers receive the productivity benefits and the public receives the offsite benefits, benefit-cost ratios can be estimated for the public and for private farmers. These benefits divided by their associated conservation expenditures are shown in table 12. The public benefit-cost ratios for the programs range from a low of 0.4 for the GPCP to a high of 2.7 for the CTA only program and average 0.9 for all programs. The high public benefit-cost ratio for the CTA only program is due to the low proportion of public costs associated with adoption of conservation measures under this program in comparison with the large erosion reduction and corresponding large offsite benefits. The low public benefit-cost ratio for the CTA with ACP cost-share programs is because of the high public expenditure per acre of the cost-share program. The low public benefit-cost ratio for the GPCP is due to the low offsite benefits per ton of soil saved in the Great Plains, in part, because offsite wind damage reduction benefits were omitted. On average the programs appear to about break even for the public. The estimated private returns, however, are much lower.

The private benefit-cost ratios range from a low of 0.3 for the CTA only program to a high of 0.8 for the CTA with ACP cost-share programs and average 0.5 for all programs. Part of the difference in private benefit-cost ratios between the CTA only and the CTA with ACP cost-share programs is due to government cost-sharing. The low private benefit-cost ratios

Table 12--Public and private benefit-cost ratios

Conservation program	Public offsite	Private long-term productivity
	Benefit-cost ratios	
CTA with ACP cost-share 1/	0.5	0.8
CTA only 2/	2.7	.3
ACP cost-share only 3/	.9	.6
GPCP 4/	.4	.5
Total	.9	.5

1/ Conservation Technical Assistance with Agricultural Conservation Program cost-share.
2/ Conservation Technical Assistance only.
3/ Agricultural Conservation Program cost-share only.
4/ Great Plains Conservation Program.

highlight the importance of the joint production and conservation benefits associated with conservation practices. Since we did not have data to estimate all the shortrun production benefits and costs, the costs attributable to protecting soil productivity may be overstated. 6/ If this is true, the private long-term soil productivity benefit-cost ratios are understated. These results also point out the need to compile reliable economic data about conservation practices that will enable their costs to be properly apportioned between shortrun production versus long-term conservation purposes.

Conclusions and Policy Implications

The data clearly indicate that increased benefits are associated with soil conservation investments on cropland with higher pretreatment soil loss rates. On the average when conservation practices are applied to cropland with an erosion rate of about 15 tons per acre, the benefit-cost ratio exceeds 1.0. However, about 40 percent of the estimated cropland treated in 1983 had erosion rates of 5 tons per acre or less. About a third of the dollars spent on erosion control programs on cropland were allocated to this category. Productivity benefits on this land are very low and offsite benefits, which are related to total tons of erosion reduced, are also low. This implies that overall conservation program efficiency could be increased by spending a higher proportion of the conservation dollars on lands eroding at high rates. It is important to note, however, that not all cropland with high erosion rates is losing soil productivity at a rate that justifies conservation practices from an economic standpoint. For example, some deep loess soils have very low erosion-productivity loss impacts. Conversely, some shallow soils have large productivity losses from relatively low erosion rates. Procedures to estimate specific economic impacts of onsite productivity losses (such as EPIC) and offsite benefits on specific soils need to be employed to target funds more efficiently.

Our findings support the view that conservation program goals need to emphasize the reduction of offsite damages as well as productivity losses. Offsite benefits may account for nearly two-thirds of the total benefits of conservation programs, whose primary purpose is cropland erosion control. Some programs such as the Rural Clean Water Program already recognize the offsite benefits of conservation. Many current program goals, however, are focused on maintaining soil productivity. Program criteria designed to maintain soil productivity are not necessarily the most effective criteria to achieve the reduction of offsite damages. When both offsite and productivity benefits are combined, the benefits exceed the costs on soils with high erosion rates.

The study underscores the need to integrate economic and physical criteria in defining acceptable soil erosion limits. The data suggest that achieving soil erosion tolerance (T) values does not necessarily result in an economically efficient outcome. Consideration of both economic and physical criteria should ultimately lead to more effective use of USDA conservation dollars.

6/ The potential underreporting of the shortrun benefits and costs are discussed in the appendix.

IMPLICATIONS FOR POLICIES AND PROGRAMS*

Results of this study reinforce initiatives that conservation agencies are now undertaking to increase program benefits, reduce program costs, or both. These include: (1) continuing efforts, begun in 1981, to target program activities to areas and soils where benefit-cost ratios are highest, (2) increasing recognition of offsite damage reduction as a major benefit of USDA soil erosion control programs, and (3) modifying the conservation program delivery system to target financial and technical assistance to highly erodible land. The study points out the need to include data in the Conservation Reporting and Evaluation System to estimate both shortrun production and conservation benefits resulting from erosion control practices. In addition, the study identified needed improvements in the data base and analytic procedures for evaluating conservation programs.

Target Erosion Control Programs

In 1981, SCS moved to target an increasing proportion of soil erosion programs to areas of high erosion rates, and ASCS began targeting its ACP program in 1982. The success of these efforts was assessed in a separate intergency study (30). The logic of program redirection, initiated as a major policy in the 1982 RCA, is reinforced by the results of that study. In addition to targeting to high-erosion areas, program assistance could be directed specifically to lands where onsite and offsite damage reductions due to erosion control are the greatest.

However, targeting will not guarantee that conservation benefits exceed costs. On average, the benefit-cost ratios in this study exceed 1.0 on croplands eroding in excess of about 15 tons per acre. On lands with deep topsoil, the productivity loss may be low, resulting in a low economic return to conservation activities for these particular soils. Alternatively, conservation activities on some croplands with thin topsoil layers may result in benefits exceeding costs at erosion rates below 15 tons per acre.

Include Offsite Damage Reduction as an Erosion Control Benefit

Based on our estimates, offsite benefits of erosion control exceed benefits from the maintenance of cropland productivity. The overall benefits to society could be improved with more recognition of offsite benefits in program planning.

Offsite benefits do not always occur in the same geographic area as the productivity benefits. That can create a problem in deciding where to allocate erosion control funds. Further, offsite damages also stem from erosion from noncropland sources that may be more economic to treat. Thus, there are two possible tradeoff problems: The allocation of limited conservation dollars between offsite and productivity objectives, and the allocation between controlling erosion from cropland and from other sources.

*This section was prepared by Roger Strohbehn assisted by Neill Schaller and Gary Taylor.

Significantly improved information on offsite damages would be required to include specific offsite benefits as a conservation objective on a comprehensive, nationwide basis. However, implementation could proceed in "designated areas," including valuable estuaries, like the Chesapeake Bay, and rapidly silting reservoirs.

Base Conservation Incentives on Public Benefits

Economic returns to conservation programs could be increased by redesigning conservation incentives and the technical assistance delivery system. An example of a more efficient incentive approach is variable cost-sharing initiated under the ACP program in 1982. It is now being tested on a voluntary basis in 265 counties by ASCS to see if it can be extended to all counties (55). Lowering the Federal share of the cost of conservation practices on less erodible land relative to more erodible land could have a targeting effect and permit redirection of funds to land with higher erosion rates. These effects are confirmed by initial results of the ASCS test. Other incentive methods could be designed that would provide financial incentives to producers that are commensurate with the public benefits received from the adoption of conservation practices.

The Conservation Technical Assistance program of SCS is a voluntary program to provide conservation advice and technical assistance to producers who request these services. Greater attention should be given to tailoring the CTA program so that a larger proportion of the technical assistance is directed to the highly erodible land within each conservation district.

Estimate Erosion Control Benefits and Costs

Additional farm level economic impact data should be gathered as part of the Conservation Reporting and Evaluation System used by SCS and ASCS to document program accomplishments. Data are needed not only to estimate onsite productivity and offsite environmental benefits, but also to indicate how conservation practices affect producers' shortrun profit and loss statements. Conservation practices that have both shortrun production and conservation benefits need to be assessed so that the costs of adopting the practice are properly allocated between the two objectives. Reliable data on the costs of implementing conservation measures are essential, along with estimates of how these measures affect the producer's current year net income situation.

Improve Research and Data for Program Evaluation

Conducting program analysis in an economic efficiency framework requires more complete information about program accomplishments and procedures for measuring the various economic benefits associated with controlling all forms of erosion (sheet and rill, gully, and wind). A more comprehensive review of conservation programs should also include an economic analysis of water conservation activities. Additional research and data are needed in several areas:

Ephemeral and gully erosion. Procedures are needed to estimate soil productivity loss due to ephemeral erosion to the extent that it may not be adequately reflected in the EPIC model. Similarly, procedures are needed to estimate the economic costs of farming around gullies and the income foregone from forced conversion from crop production to grasses or trees due to gullies.

Wind erosion. Procedures and data collection are needed to ascertain the shortrun onsite and offsite damages due to wind erosion from agricultural land.

Offsite benefits. Provisional national estimates of offsite damages due to water-related erosion on agricultural land are available. The statistical information base of these estimates needs to be strengthened and extended to serve national and State level program planning objectives. Special attention is needed to estimate the cumulative value of annual marginal changes in erosion reduction and their implications for reaching threshold levels in pollutant reduction that can be translated into changes in offsite benefits.

Conservation tillage. Better information is needed on the costs and benefits of conservation tillage under different soil and climatic conditions across the Nation. In particular, procedures and data are needed to determine changes in shortrun net returns to farmers from adopting conservation tillage versus costs that should be ascribed to the protection of soil productivity. More information is needed on yield changes as well as changes in fuel, labor, pesticides and other inputs as farmers shift from conventional tillage to conservation tillage.

CRES data. CRES data forms provide physical data to describe how the conservation programs are being implemented. Estimates of the installation costs of conservation practices, however, need to be improved through standardized procedures used to calculate annual conservation practice costs. This would enable more reliable cost effectiveness analyses to be made. Evaluation of the efficiency of conservation programs, however, requires information about yield, crop mix, and input changes that affect joint shortrun production and long-term conservation benefits. In short, information is needed to derive the economic consequences of conservation practices directly from the CRES records or estimated indirectly based on physical data about changes in yields and production costs. A key item that should be maintained on the CRES form is the soil record number. This soils identification number is critical for linking CRES and EPIC data to estimate long-term soil productivity benefits from specific conservation investments. In addition, a national sampling procedure for obtaining CRES data should be developed to provide statistically reliable estimates of the benefits and costs for all conservation programs.

EPIC coverage. Soil scientists have identified about 10,000 soil groups with unique soil characteristics that affect their use and management. Only 550 representative erodible soils have been included in the EPIC model. Additional soil groups should be incorporated in EPIC to enable a closer match between the soil treated from the CRES record and the EPIC representative soil used to measure the erosion-productivity loss relationship.

Soil loss tolerance. Recently developed soil productivity models reveal that the decline in productivity per ton of soil erosion is generally less than implied by the established soil loss tolerance levels. Procedures and data are needed to establish erosion tolerance levels to protect long-term soil productivity based on scientific evidence rather than subjective expert opinion. The EPIC model provides the basis for developing productivity soil loss tolerance levels for important erodible soils. Data on the costs of adopting soil conservation practices are also needed to determine the economic feasibility of reducing erosion on soils that have high productivity losses.

Erosion impacts on pasture and range land. Procedures and data should be developed to estimate the economic benefits of erosion control practices on pasture and range land. The procedures should distinguish between impacts of conservation practices on shortrun net returns versus longrun productivity protection.

Water conservation benefit analysis. USDA allocates about 10 percent of its conservation budget to water conservation. Concepts, procedures, and data are needed to conduct an economic analysis of water conservation programs.

APPENDIX--BENEFIT AND COST ESTIMATION*

The five major components of our benefit and cost analysis are discussed in this appendix: (1) The basic data source for much of the analysis, USDA's Conservation Reporting and Evaluation System (CRES), (2) procedures for obtaining the erosion reductions under the three major soil conservation programs, which form the basis for assigning offsite and productivity benefits to each program, (3) cost estimates for the three programs, (4) the estimation in dollars of productivity benefits of reducing soil erosion, and (5) estimation of the value of offsite damage reductions. Limitations associated with these data sources and procedures are also discussed.

Data

The estimation of onsite soil productivity and offsite benefits requires significantly different procedures and data. Erosion reduction, along with program costs, were estimated using 1983 data from USDA's Conservation Reporting and Evaluation System (CRES).

We used data from a 227-county sample obtained from CRES files. The sample was a stratified two-stage cluster design. Counties, the primary sampling units, were selected randomly from within strata. All installed practices under the Agricultural Conservation Program, the Conservation Technical Assistance Program, and the Great Plains Conservation Program were described on 1983 CRES data sheets. The CRES data also included: (1) State and

*Methods and procedures used to estimate the productivity benefits and erosion control costs in the study were developed by Daniel Colacicco and Alexander Barbarika. Marc Ribaudo and C. Edwin Young developed the estimates of the offsite benefits used in the study.

county location, (2) land use, (3) purpose of conservation practice, (4) number of acres affected, (5) land class and subclass of the soil, (6) soil loss tolerance value, (7) type of practice applied, (8) installation cost, (9) amounts of cost-sharing and technical assistance, (10) before-and-after sheet and rill erosion, (11) wind erosion, and (12) other types of erosion. The number of sample counties and conservation practice installations on cropland for the programs analyzed are listed in appendix table 1.

The total sample data for the three USDA programs analyzed consisted of 31,597 records that provided erosion reduction data for all land uses. These data yielded an estimated 39.3 million acres affected by erosion, and an erosion reduction of 827 million tons of soil over the service life of the practices installed (app. table 2). However, 20 percent of these records indicated that practices were applied for reasons other than erosion control and that erosion reductions that occurred were secondary impacts. To keep the focus of the analysis on erosion control, these records were deleted from the analysis. Of the remaining records, 70 percent (18,147) described practices applied to 16.5 million acres of cropland for which we could estimate productivity benefits. The analysis focused on these 16.5 million acres.

Our estimates of cost-sharing and technical assistance in appendix table 2 are less than the program estimates shown in figure 2. The CRES estimate for cost-share payments to producers for erosion control under the ACP program in 1983 is $101 million (i.e., $124.4 million as reported in appendix table 2 minus $23.4 million in administrative costs). This is

Appendix table 1--Number of CRES observations for cropland, erosion control purposes

Region	Cropland	
	Counties	Installations
	Number	
Appalachian	35	3,028
Corn Belt	25	2,380
Delta States	34	2,157
Lake States	9	724
Mountain	13	1,333
Northeast	14	1,274
Northern Plains	20	1,548
Pacific	9	552
Southeast	18	1,295
Southern Plains	34	3,856
United States 1/	211	18,147

1/ Of the 227 sample counties, 16 counties had no data for installations on cropland.

Appendix table 2--Selected CRES data, 1983

Program	All erosion impacts					Erosion control purpose					Erosion control on cropland				
	Obser-vations	Acres	Tons	Cost 1/ share	Tech. ass't.	Obser-vations	Acres	Tons	Cost share	Tech. ass't.	Obser-vations	Acres	Tons	Cost share	Tech. ass't.
	Number	- Million -		Mil. dol.		Number	- Million -		Mil. dol.		Number	- Million -		Mil. dol.	
CTA with ACP cost-share	10,670	7.0	244.4	128.3	92.2	8,823	4.8	219.8	106.2	76.7	6,075	3.7	170.7	80.1	60.6
CTA only	17,750	30.2	484.0	0	61.5	14,484	20.2	394.3	0	48.6	11,030	12.1	198.9	0	35.1
ACP cost-share only	2,892	.8	22.7	16.3	.3	2,774	.7	20.6	15.2	.3	915	.4	8.5	7.2	.2
GPCP	285	1.4	75.8	4.1	3.3	212	.6	17.1	3.0	2.8	127	.2	6.9	1.3	1.7
Total	31,597	39.3	827.0	148.7	157.3	26,293	26.3	651.8	124.4	128.3	18,147	16.5	384.9	88.5	97.6

1/ All cost-share data include administrative costs.

20 percent below the corresponding estimate of $131.1 million for the ACP cost-share payments shown in figure 2. The CRES estimate of Federal technical assistance of $128.3 million is very close to the estimate in figure 2 of $130.7 million. The small number of sample observations for the GPCP makes comparisons with actual program data difficult.

There are many possible reasons for the difference between the CRES estimates and actual program data. The CRES data are a statistical sample as opposed to a complete enumeration, and all the cost-shared practices in the sample counties may not have been reported. In addition, some observations were deleted from the data set because of incomplete or inconsistent responses. Thus our estimates of total tons, acres, costs, and benefits are to some extent underestimated. However, this difference will not be a source of bias for estimated benefit-cost ratios if uncounted installations have costs and benefits similar to those for recorded installations.

The CRES system is a valuable source of data, indispensable for evaluating conservation programs. However, the system was new and expanding in 1983 when the data for this study were collected, and the reliability of the system has increased since then. ASCS and SCS developed the CRES system to evaluate their conservation activities and have used the 1983 data to evaluate the ACP and CTA programs. We would have preferred to use 1984 CRES data, but those data lacked critical soil identification information needed to link CRES data to other sources of data for estimating the productivity benefits of the conservation practices.

The coefficients of variation (CV) on the national estimates generated from the CRES data are very low, which indicates good reliability of the national estimates (app. table 3). The individual program CVs indicate reliable estimates can be made for the CTA only and CTA with ACP cost-sharing program combinations with the CRES data. The CVs are relatively high for the ACP only and the GPCP programs which indicates the lower reliability associated with our estimates of these programs. Statistical measures of reliability can only be made for estimates generated by sampling. Part of the analysis in this study uses estimates which do not come from a statistical sample. For example, productivity value per ton estimates and offsite damage estimates were derived from a variety of data sources and procedures described in the next section. Thus, the variation of the reported economic estimates used in the benefit-cost analysis are unknown. However, given the uncertainties surrounding the models and data sources we would expect the variation of our estimates to be quite large.

Erosion Reduction Estimation Procedures

CRES data provided estimates of the reduction in erosion attributable to the 1983 soil conservation programs. We assumed that the erosion control programs conserved soil only on farms receiving direct technical assistance or cost-sharing. No data were available to estimate erosion control efforts by nonparticipating farmers who were encouraged to do so by program results on other lands. We also assumed that the level of erosion reduction on farms receiving assistance would have been less without Federal assistance.

Appendix table 3--Coefficients of variation for selected variables from the CRES data

Program	CRES forms	Counties	Acres	Erosion reduction	Erosion reduction per acre	Installation cost
	--- Number ---		---------------	Percent	---------------	
CTA with ACP cost-share	6,075	174	18	14	18	11
CTA only	11,030	192	10	18	13	19
ACP cost-share only	915	42	42	43	41	27
GPCP	127	24	36	49	22	30
Total	18,147	211	10	14	11	12

The erosion reductions occurring because of USDA conservation programs were assumed to extend over the service life of the practices implemented. The service life of the practices was defined by SCS and ASCS, with one exception. SCS and ASCS revised the service lives midway through the study, and the changes are reflected in this analysis. No consensus was reached on the service life of conservation tillage. One could expect that conservation tillage, because of its potential to improve shortrun net returns, would be adopted by farmers without assistance. But USDA assistance should accelerate adoption. In such cases, the benefit period attributable to the Federal assistance would be less than the service life of the required tillage equipment. We assumed a benefit period of 5 years for no-till, 1 year for reduced tillage when applied with ACP cost-sharing, and 3 years if the CRES form did not specify a conservation tillage method. This is different from previous SCS and ASCS evaluations which used 1 year for all conservation tillage methods.

The service life for all practices on a CRES form for ACP cost-shared practices was determined by the service life for the specified program practice code as assigned by ASCS, with the exception of conservation tillage noted above. CTA CRES records had no program practice code and the service life used was the longest service life of the individual technical practices other than contour farming. We had to choose a single service life per record because there was no way to partition the erosion reduction on records that reported several technical practices. Contour farming is a low-cost but long-lived (10 years) practice that was often installed with much more expensive annual practices, disproportionately weighting the CRES records containing contour farming in the analysis.

Contour farming, when used in combination with other practices, was not permitted to determine the service life of the practice mix.

The three conservation programs were estimated to reduce soil erosion by 385 million tons on cropland over the lifetime of conservation practices initiated in 1983 (app. table 4). Two-thirds of the erosion reduction came from sheet and rill erosion, one-fifth from wind erosion, and the remaining tenth was from gully erosion. The programs are grouped as reported in appendix table 4 because the data would not permit independent evaluation of each program. Farms that received both SCS technical assistance and ASCS cost-sharing achieved twice as much erosion reduction per acre as the farms that received help from single programs.

Cost Estimation

The cost of installing the federally subsidized conservation measures was also obtained from the CRES data form. The costs of installation, public cost-shares, and public technical assistance are reported for each practice. Only costs associated with practices installed for the purpose of erosion control were included in the analysis. The costs of the practices as reported on the CRES form are not always complete. For example, the opportunity cost of taking land out of production for terrace back slopes or shifting to permanent vegetative cover are not included, nor is the cost of extra labor and fuel for farming bench terraces included.

Appendix table 4--Erosion reduction on cropland from federally assisted practices 1/

Conservation program	Area 2/	Sheet and rill	Wind	Other	Total	Erosion reduction
	1,000 acres	--------- 1,000 tons			---------	Tons per acre
CTA with ACP cost-share	3,721	124,865	24,040	21,819	170,724	45.9
CTA only	12,094	137,788	47,423	13,640	198,851	16.4
ACP cost-share only	408	7,125	950	378	8,453	20.7
GPCP	235	3,203	3,488	174	6,864	29.2
Total	16,457	272,980	75,901	36,011	384,892	23.4

1/ Erosion control purposes only.
2/ Affected by sheet and rill, wind, or "other" erosion.

In many cases, several practices were installed together to resolve an erosion problem. The cost data for each practice is included as a separate item on a common CRES form, while only the resultant erosion reduction from the practice mix was reported. The individual practices may have different service lives and the practices with the shorter lives have to be reinstalled to maintain the stated erosion reduction to the end of the service life of the longest lived practice. To obtain a cost estimate commensurate with the benefit estimates, which were based on erosion reduction for the life of the longest lived practice, we converted all costs of installation, operation, and maintenance for each practice to annual costs. The present value of a stream of the practice's annual costs for the designated service life per CRES form determined the cost of installation, operation, and maintenance for all practices except conservation tillage.

The reliability of the installation costs on the CRES form for conservation tillage was low. There appears to be no common definition of the costs to be included. Negative costs, which would occur when production costs decline with a shift to conservation tillage, resulting in an increase in net returns to the farmer, were not permitted on the CRES form. Therefore, we used two procedures to incorporate conservation tillage costs. One procedure treated conservation tillage the same as all other practices and used the CRES data to estimate conservation tillage costs. The second procedure is based on other budget data for conservation tillage. We assumed, in this second procedure, that USDA cost-sharing or technical assistance was an incentive to increase the rate of adoption of conservation tillage and that adoption involved a one-time transition cost. The private cost (or benefit) for a shift to conservation tillage was defined as the difference in annual net return between conventional and either no till or minimum till (or a weighted average of the two if the specific conservation tillage method was not listed on the CRES form). Estimates of the differences in net return for the second procedure were generated from modified budgets supplied by the Center for Agricultural and Rural Development (CARD) at Iowa State University. If not otherwise specified, the second procedure was used to estimate costs for the analysis.

The cost of technical assistance per practice installation was estimated by multiplying the hours of technical assistance in the field, as reported on the CRES form, by an hourly rate, which was $62.50 per hour. This hourly rate was based on an estimate of $17.60 per hour of onsite assistance and a $44.90 additional charge to reflect planning time and other labor at the field, area, State offices, and national headquarters to support the onsite technical assistance. The value of onsite assistance time was obtained by dividing the $15.14 per hour valuation of assistance time from the conservation technical assistance (CTA) evaluation report by 0.86 to account for employee benefits which were not included in the basic hourly rate according to SCS personnel (64). The additional charge was derived as follows: The CTA evaluation data showed that office planning time took 0.6 hour for every hour in the field and we estimated that support activities (training, preparing technical slides, and so on) also took 0.6 hour for every hour in the field, and field office administration took 0.3 hour for every hour in the field (62). The estimates of time spent on support and administration were derived by apportioning the support and administrative activities to erosion control by the percentage of time an employee spends planning and applying erosion control activities. The CTA evaluation reported that 2,000 staff years of area, State, regional technical centers, and national headquarters time supported 5,000 staff years of field office work time in the CTA program. Thus there is about 0.4 hour of staff time above the field office level for every hour spent at the field office, or about 1 hour of support time above the field office level for every hour of onsite technical assistance time. The 1983 planning activities of the staff at all levels may not be related to the erosion reduction in 1983, so attributing these costs to the 1983 outputs may overestimate or underestimate related support costs. The same average wage was used for all SCS employees in estimating public costs. Technical assistance from both Federal and nonfederal sources were estimated to cost the same hourly rate. No costs for rent, supplies, and other nonlabor inputs were included in estimating the cost of technical assistance.

Administrative costs were included in estimating ACP costs. An estimate of the administrative cost per cost-shared installation was derived by dividing an estimate of total ACP administrative cost by an estimate of the number of installations. The estimate of the number of installations was derived by expanding the CRES sample. The estimate of ACP administrative costs was derived by apportioning the total administrative costs of ASCS for erosion control from Pavelis (32) between the ACP and the Forest Incentive Program based on cost-sharing expenditures in each program. An estimate of $150 per installation was derived using the above method. We added this figure to each cost-shared installation.

Total cost is the sum of private installation and operation and maintenance costs, Federal cost-sharing, nonfederal cost-sharing, Federal technical assistance costs, and nonfederal technical assistance costs.

Total private and public conservation costs associated with these programs was approximately $419 million in 1983, of which approximately $200 million, or half, represents public funds (see table 11). Federal expenditures constitute over 90 percent of the public funds.

Estimates of the private costs of conservation tillage have a very large impact on the estimates of total private costs, which significantly affect total costs. Private costs are reduced by almost 50 percent when CARD conservation tillage costs are substituted for the CRES tillage costs (app. table 5). Due to the sensitivity of the results to the conservation tillage costs, both cost estimates were used in the analysis to show a range of benefit-cost ratios.

Productivity Benefit Estimation

A benefit-cost analysis of USDA conservation programs to protect productivity requires estimates of the productivity benefits that would accrue to the farmer by installing federally assisted practices. Protecting soil productivity may be the motivating force behind Federal programs that reduce erosion, but conservation practices can also offer farmers short-term changes in net returns.

Appendix table 5--Private installation, operation, and maintenance costs for all applied practices with alternate sources of data for conservation tillage costs

Conservation program	Private conservation practice costs using: CRES conservation tillage costs	CARD conservation tillage costs
	Million dollars	
CTA with ACP cost-share	165.1	53.9
CTA only	230.7	154.7
ACP cost-share only	11.1	5.1
GPCP	4.9	3.4
Total	411.9	217.0

The effects of adopting conservation practices on short-term net returns can be categorized as affecting (1) opportunity costs of resource use, (2) yields, and (3) costs of production. Appendix table 6 lists the effects of the most popular conservation practices on short-term returns. Windbreaks, permanent seedings, terraces, and stripcropping result in an opportunity cost to farmers by changing the land use from crops with high income potential to lower paying crops or forest products. Conservation tillage can have a negative opportunity cost (a positive producer benefit) when it permits annual cropping in some areas that would normally lie fallow in the summer (31).

These practices also affect yield. Terraces, stripcropping, and stubble mulching increase water content of the soil, which can significantly increase yields in dry areas or during droughts (15, 43). But the increased water can be a liability in cool, wet springs by lowering soil temperature and reducing yields (15). Windbreaks have generally been observed to increase yields, sometimes as much as 20 percent (3). However, at least one study has concluded that windbreaks can reduce yields overall (27).

Many of the conservation practices affect production costs. Farming on the contour can increase tillage time by as much as 10 percent (4, 42). Windbreaks and terraces break up a field and introduce tillage inefficiencies. Conservation practices can also reduce costs. Grass waterways increase the efficiency of field operations by reducing machinery repair costs associated with crossing gullies, or by reducing the time and fuel used to turn equipment around at the edge of gullies. These savings may be partially offset by additional land being required for a grass waterway that was preempted from cultivation by the gully. In highly erodible cases, installation of grass waterways prevents gullies from becoming so extensive that crop production is precluded in the field. Windbreaks can reduce the cost of replantings due to wind damage of seedlings. Many of the farmers adopting conservation tillage methods are attracted more by the fuel or labor savings than they are by the soil savings (23). Residue management and cover crops can reduce soil bulk density and fuel requirements for primary tillage (39).

Appendix table 6--Possible economic effects of erosion control practices excluded from analysis

Practices	Opportunity cost	Yield	Cost of production
Contour farming	N	+ (43)	+ (4, 42)
Crop residue use	N	+ (39, 58) - (58)	- (39)
Windbreaks	+ (27)	+ (3) - (27)	N
Permanent seedings	+ (4)	N	N
Terraces	+	+ (20, 43)	+
Strip cropping	+	+ (11)	+
Cover crop	N	+ (38)	-
Grass waterways	+	N	-

N = Neutral
Numbers in parentheses refer to sources cited in references.

The increases in short-term net returns such as those mentioned above must be responsible for some of the private investment in federally assisted conservation practices. However, there are no representative data to measure the extent of increased short-term profits due to the adoption of conservation practices other than the conservation tillage data described earlier. Nor are there any data to measure the potential reduction in short-term profits that the adoption of erosion control practices may cause by reducing yields, increasing time and fuel requirements, or growing less profitable crops. With the exception of conservation tillage, the analysis provides only the estimated economic benefits from reducing the long-term productivity impacts of soil erosion.

Productivity Estimation Procedures

Productivity benefits of conservation practices were estimated by a two-part procedure. Aggregate estimates of the reduced erosion from federally assisted conservation practices were obtained by multiplying the CRES sample values by the inverse of the probability of selection of each observation as detailed above and aggregated by county, land use, and soil group. Then an estimate of the benefits per ton of erosion reduction for each combination of county, land use, and soil group was developed and applied to the expanded data to obtain an estimate of the total benefits.

A procedure was developed to estimate the benefits per ton of reduced erosion for each of eight soil groups and three land uses in each sample county. The RCA convention of dividing the numerous SCS land class/subclass categories into eight soil groups was adopted. Appendix table 7 shows how the land class or subclasses are distributed among eight RCA soil groups.

Because land use may have a significant effect on soil conservation benefits, the benefits per ton of erosion reduction were estimated for each land use. The CRES data identify land use as grain cropland, nongrain cropland, hay land, pasture, range, forest land grazed, and forest land not grazed. Our analytical procedure could not evaluate the productivity benefits from reduced erosion from pasture, range, or forest land. We estimated benefits only for nongrain cropland, grain cropland, and hay land. These uses are collectively referred to as cropland throughout the analysis.

The damages from gully erosion affect the returns from farming differently than sheet, rill, and wind erosion. Gully erosion may remove land from production and can reduce tillage efficiencies by breaking up fields. Thus, the benefits to gully control would be the opportunity cost of land retained in production and the reduced costs of production by maintaining field size efficiencies. However, lacking data to estimate the amount of land retained in production or reduced costs due to gully control practices, we estimated the benefits of these practices with the same procedure used to estimate the benefits from sheet and rill or wind erosion. This procedure may underestimate actual benefits of gully control practices.

The formula for estimating the present value of benefits per ton of soil saved (BT) for each county and soil group combination is:

$$BT_k = BTA_k/R$$

where BTA_k = annual benefit per ton of reduced erosion on land use k

R = real discount rate

Appendix table 7--RCA soil groups

RCA soil group	Land capability class/subclass
1	I
2	IIe
3	IIIe
4	IVe
5	IIc, IIIc, IVc
6	IIs, IIIs, IVs
7	IIw, IIIw, IVw
8	V, VI, VII, VIII (all subclasses)

The benefit stream was assumed to be infinite and irreversible. The annual benefit per ton per acre of soil (BTA_k) is a weighted average of annual benefits over the crops grown in the county on the different soil groups on land use k. The annual benefits per ton of soil (BTA_j) for the j^{th} crop were determined by the following equation:

$$BTA_j = P_j \cdot \Delta Q_j + PI_i \cdot \Delta I_{ji}$$

where:

P_j = price of crop j

PI_i = price of i^{th} input

ΔQ_j = change in yield of crop j

ΔI_{ji} = change in i^{th} input for crop j

The change in yield (ΔQ_j), assuming a linear yield response to erosion, was determined as follows:

$$\Delta Q_j = CIUY_j \cdot Q_j$$

where:

$CIUY_j$ = fractional changes in yield per ton of erosion for crop j

Q_j = initial yield of crop j

and

$$Q_j = \frac{BYF_{nj} \cdot AY_j}{\sum_n \left(BYF_j \cdot \frac{AC_{nj}}{\sum_n AC_{nj}} \right)}$$

where:

BYF_{nj} = yield of j^{th} crop on n^{th} soil as a fraction of the yield of that crop in RCA soil group 2

AY_j = average yield of j^{th} crop

AC_{nj} = acres of crop j on n^{th} soil group

The use of inputs, such as nitrogen, phosphorus, and lime, can be expected to change due to erosion. The change in these inputs was determined as follows:

$$\Delta I_{ji} = CIUI_{ji} \cdot CIIY_{ji} \cdot Q_j$$

where:

$CIUI_{ji}$ = fractional change in i^{th} input per ton of erosion for crop j

$CIIY_{ji}$ = application rate of i^{th} input per unit of yield of j^{th} crop

Estimation of benefits per ton of erosion (BT_k) required data for R, P_j, PI_j, $CIUY_j$, BYF_j, AY_j, AC_{nj}, $CIUI_{ji}$, and $CIIY_{ji}$.

Commodity prices (P_j) were derived from published USDA normalized prices with an adjustment to subtract the price-enhancing effects of Government programs. Use of the unadjusted prices would increase total benefits by less than 10 percent. The 1983 adjusted normalized prices do not reflect commodity price support subsidies and, therefore, provide a better estimate of the true social value of the commodities. The Crop Reporting Board's data on national input prices were used for the prices of nitrogen, phosphorous, and lime.

This procedure implicitly assumes that the conservation programs have no effect on prices of commodities, and thus will underestimate program benefits to the extent that the programs reduce prices by maintaining soil productivity. However, the yield changes were of such a small magnitude that we believe that the loss of consumer surplus due to erosion would be small. We assumed future real prices of commodities and inputs to be unchanged. If the real price of fertilizer does increase due to energy price increases or declining reserves, the benefits from erosion control will be larger than estimated. Real increases in the price of food and fiber will also result in greater benefits to erosion control than reported.

County yield data (AY_j) were supplied by the Center for Agriculture and Rural Development (CARD), Iowa State University, and were based on the 3-year average county yield data provided by the Statistical Reporting Service. The acres by crop for each soil group in each county (AC_{nj}) were determined from SCS's National Resources Inventory (NRI) data. Because the NRI data are less reliable at the county level, we assumed that the distribution of acres in a crop among soil groups was the same for all counties within a Major Land Resource Area (MLRA).

USDA's Erosion Productivity Impact Calculator (EPIC), provided estimates of fractional change in yield per ton of erosion ($CIUY_j$), the relative yield potential of each soil group (BYF_j), the fractional change in inputs per unit of output per ton of erosion ($CIUI_j$), and the application rate of the inputs per unit yield ($CIIY_{ji}$) (70). $CIUY_j$ and $CIUI_j$ were assumed to be independent of total erosion. These variables were produced by the EPIC team for soil groups 2, 3, 4, and 8 in most MLRA's because these soils have the greatest erosion problems. However, there are significant erosion problems on soils in the other soil groups, and we assumed that the RCA soil groups 1, 5, 6, and 7 would suffer the same impacts per ton of erosion as soil group 2. The EPIC data were produced on an MLRA basis and were used to represent all the counties within the specified MLRA.

Our procedure ascribes productivity benefits to all reductions in erosion, including reductions below the soil tolerance (T) level. Since the T-value is defined as the maximum rate of erosion with no productivity loss, it can be argued that erosion reduction on land eroding at less than T should have no productivity benefits. However, as the EPIC data suggest, T is a subjective determination and may, in fact, not be closely correlated with the maintenance of productivity. The main reason we calculated benefits for soils with low erosion rates was because our input data, the EPIC data, did not incorporate the T concept in determining the yield and input changes due to erosion.

The real discount rate (R) has been very volatile in recent years. The rate has fluctuated widely and was even negative four times in the last 12 years. The rate has risen the last few years. We chose a 4-percent rate because it is close to the average real rate of the last 5 years.

We implicitly assumed no effect due to technology changes in this analysis. Technology could increase productivity, thereby reducing commodity prices and reducing the benefits of erosion control. However, technology may be complementary to soil quality in crop production, which would make the yield reductions due to erosion and the benefits of erosion control greater with technological advances.

Even if the loss of topsoil has only a small effect on average yield, it may have a large effect on the variation of yield. If the water-holding capacity and water infiltration rate are reduced by removal of topsoil, then the yield depression caused by low precipitation will be exaggerated. This increase in the variation of yield may have costs to the farmer and society which are not included in this analysis, and thus bias the benefit estimate downward.

Productivity Benefits Per Ton of Reduced Erosion

The productivity benefits per ton of reduced erosion are the yield and input losses avoided by the adoption of the practices. Productivity benefits per ton of reduced erosion are generally greater on the better soils. Appendix table 8 shows that the average value of a ton of reduced erosion declines from soil group 2 (IIe) to soil group 3 (IIIe) and to soil group 4 (IVe). The least capable soils, group 8, are only two-thirds the value of group 2 soils. However, the relationship between soil groups changes from region to region. In five regions, the value declines as the soil capability decreases. In the other five regions, the average value per ton increases or remains the same as the soil capability decreases.

The value per ton of soil estimates are the present value of a constant annuity to perpetuity. The economic benefits of a conservation practice are the present value of all the soil conserved by the practice over its useful life. The given practice is assumed to conserve the same amount of soil each year. Thus, the economic benefit per practice is the present value of an increasing annuity to the end of the practice life plus a constant annuity from the end of the practice life to perpetuity.

Appendix table 8--Average productivity benefits by RCA soil group and farm production region, dollars per ton of erosion reduction 1/

Region	RCA soil group			
	2	3	4	8
	Dollars			
Appalachian	0.36	0.26	0.32	0.19
Corn Belt	.64	.31	.20	.25
Delta	.06	.29	.10	.22
Lake	.62	.36	.17	.20
Mountain	.26	.26	.29	.26
Northeast	1.25	.83	.43	.16
Northern Plains	.42	.31	.25	.31
Pacific	.17	.07	.31	.61
Southeast	.07	.25	.19	.22
Southern Plains	.25	.28	.21	.26
United States	.40	.30	.23	.25

1/ Assumes a 4-percent discount rate.

Offsite Benefit Estimation

Offsite benefits from the soil conservation programs are the reductions in economic damage caused by sediment and other agricultural pollutants. We estimated damage from all sources of erosion (cropland, range, pasture, forests, roads, construction sites, pits, mines, quarries, and streambanks), and used them as a basis for estimating benefits from reducing erosion on cropland. The major source of information on damage was a report by Edwin Clark, for the Conservation Foundation (7), which made national estimates of offsite damages from soil erosion for a number of damage categories. For each category, Clark reported a range of damage estimates, and what he considered to be the "best" estimate (not necessarily the midpoint). This range reflects large uncertainties in the data used and the assumptions made in generating the damage estimates. In almost all cases, damage estimates for small geographic areas were expanded by Clark to the national level. This procedure leads to estimates with very large ranges of confidence. However, we felt that Clark's range of estimates are as good as current data allow, and they are the only comprehensive set of estimates available.

Ten categories of instream and offstream impacts identified in Clark's study are addressed in this report. These are the most important impacts from soil erosion for which damage estimates can be made. Clark's "best" estimates of damage were used as a starting point. The procedures used to estimate the damages in each category are treated individually. All values are reported in 1983 dollars, unless stated otherwise.

Instream Effects

Instream effects consist of erosion's impacts on recreation, water storage, navigation, and commercial fishing.

Recreation uses affected by erosion include freshwater uses and marine fisheries. Soil erosion has a variety of detrimental impacts on freshwater recreation activities, including the destruction of fish habitat, siltation of recreation facilities, and eutrophication of waterways. Clark estimated annual damages to freshwater fishing, boating, and swimming from erosion at $1.9 billion. This value was based on the results of other studies.

In a recent review of research, Freeman reported estimates of damage to freshwater swimming, boating, and fishing from all sources of water pollution, including nonpoint (12). Vaughn and Russell estimated the benefits to freshwater fishing from all planned point source controls, plus 100-percent cropland sediment control (69). Elimination of cropland sediment accounted for 13-17 percent of total benefits. These percentages were applied to Freeman's values to arrive at an estimate of damages to freshwater swimming, boating, and fishing from cropland erosion. Since cropland contributes about one-third of all sediment discharged into waterways, this estimate was expanded to include all erosion sources by multiplying it by 3.

Soil erosion not only affects freshwater fisheries, but can also have a detrimental impact on marine fisheries. Many important fish species depend on coastal estuaries for spawning grounds or nurseries. Sediment and nutrients from erosion can harm these sensitive ecosystems. Clark estimated that erosion damage to the marine sport fishery is about $544 million per year. This value was calculated in the same way as for freshwater fishing. The percentage of erosion's contribution to total damage calculated for freshwater fishing was applied to Freeman's estimate of total damage to marine fishing from all sources of pollution. This approach assumes that erosion's contribution to damage in coastal waters is the same as for freshwater damages.

Water storage facilities can be affected by siltation caused by erosion, which reduces water storage capacity. Clark reported three major categories of costs to water storage facilites, totaling $1.1 billion. These are: (1) additional capacity in new reservoirs to account for sediment; (2) dredging; and (3) lost storage capacity. Damage for these three categories were calculated with data from a variety of studies. Costs of additional capacity in new reservoirs to account for sediment were based on estimates of capacity construction rates and reservoir construction costs. Dredging costs were based on an estimate produced by the Federal Water Pollution Control Administration. Lost storage capacity costs were based on estimates of capacity replacement costs.

Navigation is affected by erosion-caused siltation of channels and harbors. Damage is equal to the cost of keeping these waterways open. Average annual dredging costs incurred by the Army Corps of Engineers for maintaining navigable waterways are $340 million. The Corps does not perform all the waterway dredging that takes place. According to Clark and a Corps representative, the Army's activities make up about half of all dredging, the rest being conducted by State and local authorities. The costs provided by the Corps were therefore doubled to arrive at total dredging costs of $680 million.

Commercial fishing is also affected by erosion. Freeman estimated that likely damage to commercial freshwater fishing from all manmade pollutants is probably no more than $150 million per year (12). Assuming that the relationship between damage to recreational fishing and the contribution from erosion holds for commercial fishing (as reported in Clark), the damage from erosion is about $55 million per year.

Soil erosion can harm marine fisheries. The primary impact is on estuaries, which are the principal spawning grounds for many important commercial species of shellfish and fin fish. One study reported damage to marine fisheries from all sources of water pollution at $1,065 million per year (12). Assuming that the relationship between damage to recreational marine fishing and contribution from erosion holds for commercial fishing, the damage from erosion is about $355 million per year.

Offstream Effects

Soil erosion imposes costs not only on the users of waterways, but also on activities outside the stream channel. The degradation of water quality imposes costs on the users of water, such as industry and municipalities. Flooding causes damage away from the stream channel. Erosion also affects conveyance systems for moving water toward or away from waterways.

Flood damage caused by soil erosion was grouped in five categories by Clark. These include increased flood heights due to channel aggradation, increased flood volumes due to sediment loads, direct sediment damage to urban and nonurban areas, and reduced agricultural productivity. The Conservation Foundation estimated total damage from these categories at $887 million. Damage from channel aggradation was assumed to range from 0-10 percent of total upstream damage from flooding. Damage from increased flood volumes was estimated by combining the relationship between sediment concentration and water volumes with U.S. Geologic Survey measurements of sediment concentration and estimates of flood damage. Direct damage from sediment was based on estimates of total damage to property and structures from flood sedimentation. Agricultural damage from flooding was based on a study in the Piedmont region of North Carolina, which showed that productivity losses in flood plains could range up to 2 percent.

Water conveyance facilities, like roadside drainage ditches and culverts, can become clogged by sediment from soil erosion. Damage is measured by the cost of keeping these drainage systems clear. A 1977 survey of Illinois road maintenance departments concluded that 2.5 million cubic yards of sediment were removed annually from roadside ditches by State and local road crews. This represents about 1.4 percent of the gross erosion in Illinois (7). Since Illinois is in the Corn Belt, we assumed that 1.4 percent of surface erosion in the Corn Belt reached ditches. The percentage of erosion reaching ditches in the other regions were calculated by assuming a direct relationship between sediment delivery ratios (as calculated by Resources for the Future) and the percentages of erosion reaching ditches (14). These values range from 1.3 to 1.8 percent.

The amount of erosion taking place in each region was obtained primarily from the 1982 National Resource Inventory. The 1977 NRI was used for data on gully, streambank, road, and construction site erosion. Land use information from a variety of sources was used to calculate erosion from Federal land. In this way, a relatively complete accounting of erosion was obtained.

The average cost for sediment removal in the Illinois study cited above was $2.50 per cubic yard ($3.90 in 1983 dollars). This cost was assumed to be the same for all regions. Annual drainage ditch maintenance costs were calculated by multiplying gross erosion (in tons) by the percentage of erosion reaching drainage ditches, converting this to cubic yards, and multiplying by $3.90. This resulted in total damage of $214 million.

Irrigation canals also become clogged by soil runoff of sediment and nutrients, increasing maintenance costs for sediment removal and weed control. Clark reported that approximately 15-35 percent of the operation and maintenance costs for irrigation systems are attributable to soil erosion. These figures came from the operations chief at the Bureau of Reclamation. Operation and maintenance costs for 1978 were obtained from the Census of Agriculture. These costs were converted to 1983 dollars, and 25 percent (the midpoint of the range reported above) of these were identified as being erosion related. This approach resulted in total damage of $106 million.

Water treatment facilities can likewise be affected by soil erosion that deposits sediment and other contaminants in waterbodies serving as public drinking supplies. The cost of removing these pollutants is a measure of the damage. Clark reported an annual cost of $121 million for increased water treatment costs due to soil erosion. This estimate is based on information from an EPA analysis of costs of removing suspended solids and other contaminants from municipal water supplies.

Municipal and industrial users are affected because, even after treatment for suspended sediment and disease-causing contaminants, water can still contain dissolved minerals, salts, and other materials that can interfere with the efficient operation and durability of water-using equipment. Clark estimated annual removal and damage costs of dissolved materials associated with soil erosion to be $1,086 million. This value is based on recent estimates of the benefits from achieving Clean Water Act goals. These benefits are on the order of $0.7-1.8 billion dollars for households and industries from reducing total dissolved solids (TDS). Nonpoint sources are estimated to account for 80-85 percent of TDS loadings.

Steam electric power plants and other cooling water facilities run less efficiently because of sediment and algae directly or indirectly caused by soil erosion. Suspended sediment and algae can clog condensors, reducing the efficiency with which the cooling system operates. Clark reported annual maintenance costs of $54 million, an estimate based on a study conducted by the Electric Power Institute on the removal of algae from condensors. No information was available on the costs imposed by sediment in cooling water, so the damage estimate reported above is probably an underestimate.

Irrigated agriculture can be jeopardized by saline irrigation water, which can reduce crop yields. Salts can enter irrigation supplies through irrigation return flows or through erosion of saline soils. Clark reported average damage to irrigated agriculture in the West between $0.12 and $1.21 per acre. These values are based on the results of a salinity study in the lower Colorado River Basin (7). We used the midpoint of this range, $0.66, to calculate damage to irrigated acres in regions where salinity is a documented problem (14). These regions include the Northern Plains, Southern Plains, Mountain, and Pacific. We estimated total damage to irrigated agriculture at $28 million.

Summary

Annual offsite damage from soil erosion totals $7,116 million (app. table 9). Not all of this damage can be addressed by reducing soil erosion on agricultural lands (pasture, range, and cropland). About 56 percent of all soil erosion comes from agricultural land. We, therefore, assumed that about half of total damage from erosion is the maximum potential benefit from reducing agricultural erosion.

Appendix table 9--Offsite damage from soil erosion by type of damage

Activity	Low estimate	Best estimate	High estimate
		1,000 dollars	
Freshwater recreation	750,000	1,889,000	3,957,000
Marine recreation	399,000	544,000	2,178,000
Commercial freshwater fishing	48,000	55,000	75,000
Commercial marine fishing	347,000	353,000	480,000
Water storage	500,000	1,097,200	1,597,000
Navigation	400,000	680,300	847,000
Flooding	490,000	887,400	1,404,000
Drainage ditches	90,000	214,400	224,000
Irrigation ditches	45,000	106,500	145,000
Irrigated agriculture (salinity)	4,000	27,700	42,000
Municipal water treatment	50,000	121,000	605,000
Municipal and industrial users	500,000	1,086,300	1,452,000
Steam electric powerplants	23,000	54,300	83,000
Total	3,646,000	7,116,000	13,089,000

Damage to freshwater recreation is greater than for any other category. This conclusion parallels other water pollution studies, which generally show recreation realizing the most damage. Soil erosion's impacts on industrial and municipal water users, and water storage facilities, are also quite high.

The damage estimates should be treated with some caution. The damage categories are not a complete list. Some impacts could not be measured, such as biological diversity, human health, and the aesthetic appearance of the environment. The exclusion of these impacts does not imply that they are insignificant.

A potentially large category of damage not included is the offsite damage from wind erosion. Blowing soil can damage households, businesses, and public services. Preliminary results from a study in New Mexico indicate that annual offsite damages from wind erosion originating on cropland and rangeland may approach $500 million (34). Between 1981 and 1984, from 500,000 to 15 million acres of land were damaged each year from wind erosion in the 10 Great Plains States. Approximately 14 million people live in the areas most prone to significant amounts of wind erosion.

The offsite damage from wind erosion has not been adequately quantified to generate benefit estimates, as has damage from water-induced erosion. Much more research is needed to determine the extent and magnitude of off-site offsite wind erosion damage related to cropland.

To reflect uncertainties in the damage estimates, we present high and low estimates in appendix table 9. These estimates are based on the ranges of damage values presented by Clark. It is reasonable to expect that actual damage falls within these ranges.

Estimation of Benefits

The offsite benefits of the 1983 programs were estimated using CRES data and the damage estimated in the previous section. Benefits were calculated for erosion control on cropland from practices installed specifically to control sheet and rill erosion.

This analysis required that the damage reported in the previous section first be allocated by regions (app. table 10). The disaggregation of the national damage estimates generally consisted of developing weights based on some logical proxy for damages. We then used these weights to allocate the damage estimates among the regions. This procedure was necessary for the damage that could not be estimated directly at the regional level.

The approach we used to develop regional estimates of offsite damage is far from ideal. Estimates should be developed directly at the regional level, using regional data. The use of proxies for regionalizing national damage estimates may not account for all factors that lead to regional differences.

The procedure we used to estimate benefits was to determine the percentage reduction in soil erosion in a region, and to apply that estimate to offsite damage. A linear relationship between damage and erosion was assumed, so

Appendix table 10--Total offsite damage from soil erosion by region

Region	Damage from all sources	Damage from agricultural sources
	Dollars	
Appalachian	535,000	257,000
Corn Belt	934,000	719,000
Delta States	486,000	267,000
Lake States	524,000	393,000
Mountain	815,000	440,000
Northeast	1,032,000	392,000
Northern Plains	331,000	182,000
Pacific	1,348,000	512,000
Southeast	369,000	148,000
Southern Plains	742,000	416,000
United States	7,116,000	3,985,000

that the percentage reduction in damage is equal to the percentage reduction in erosion. Offsite benefits are equal to the reduction in offsite damage. A major assumption is that there is no compensating increase in streambank erosion. If streambank erosion does increase after sediment loads from other sources are decreased, then offsite benefits would be overestimated.

We modified this procedure when we actually applied it in order to take into account several factors. First, many of the practices used by farmers have a service life longer than 1 year. An investment in a multiyear practice would generate a stream of benefits over the life of the practice. The benefits from a program that promotes a variety of practices with different lifespans would be equal to the sum of the present values of the individual benefit streams. A benefit stream was calculated for each of 12 lifespan categories.

The second factor to be considered was that the relationship between erosion and damage differs between activities. Three general damage categories were identified: recreation and commercial fishing, drainage and irrigation ditches, and water storage, flooding, navigation, and industrial and municipal water withdrawals. A separate benefit estimation procedure had to be developed for each category. The three procedures are outlined below.

We estimated the benefits from reduced maintenance costs for drainage ditches and irrigation canals by assuming a direct relationship between sheet and rill and gully erosion, and damage. We assumed that streambank erosion has no impact on ditches and canals, enabling the linear relationship between erosion and damage to be assumed. For each region, we determined the sheet and rill and gully erosion reductions for each lifespan category from the CRES data. These values were divided by total erosion from all sources within the region, except streambank, to calculate the percentage reduction in erosion. These percentage reductions were then applied to damage in the region, resulting in separate benefit estimates for each lifespan category in the region. We then calculated the present value of the benefit stream for each lifespan category and summed the values to arrive at an estimate of benefits to ditches and irrigation canals from reducing soil erosion.

We estimated the benefits to water storage, navigation, water withdrawal, and from reduced flooding in the same manner as for ditches and canals, except that we assumed a direct relationship between eroded material reaching waterways and damage (as opposed to gross erosion and damage). Percentage reductions in sediment loadings were applied to regional damages to estimate benefits. Streambank erosion reductions were included. Waterway loadings of sediment were calculated with sediment delivery ratios developed by Resources for the Future (RFF) (13). These are defined as the portion of gross erosion reaching streams. This differs from the more common definition of the portion of gross erosion leaving the watershed, which was not deemed useful for assessing offsite benefits from erosion control. We assumed that streambank erosion has a sediment delivery ratio of one. Sediment delivery ratios from other erosion sources ranged from 0.3 to 0.5. To calculate benefits, the percentage reduction in eroded material being discharged into waterways was applied to regional offsite damage.

The estimation of benefits to recreation and commercial fishing, both freshwater and marine, required a much different procedure. We assumed damage to recreation and commercial fishing to be dependent upon the ambient concentrations of pollutants in waterways. To examine these impacts, we divided each region into aggregate watershed subarea units (ASA's) and calculated the pollutant concentrations within ASA's using unpublished data from the National Stream Quality Accounting Network (NASQUAN). If the level of suspended solids, total phosphorus, or total nitrogen was greater than threshold levels, we assumed uses in the region to be adversely affected (72). A reduction in the soil erosion component of the pollution load would reduce the concentration of pollutants in ASA's (assuming no compensating streambank erosion). There is some question as to whether the NASQUAN data can be used to characterize the water quality of an ASA. However, the NASQUAN data were deemed the best available.

For each region, we converted the total amount of reduced erosion to pollutant-loading reductions by using the sediment delivery ratios and attached pollutant coefficients calculated by RFF (14). We assumed linear relationship between ambient water quality concentrations and pollutant loading, calculated percentage reductions in loadings for the region, and applied to pollutant concentrations in the ASA's of the region. We examined each ASA. If the ambient concentrations of all pollutants dropped below the threshold level, we calculated the benefits by determining the reduction in the amount of the activity being affected by poor water quality.

This procedure makes the assumption that benefits are generated only when the threshold levels are passed. When pollutant concentrations remain above the thresholds after erosion reductions (water quality remains poor), this assumption is probably a good one. Fish cannot survive above a certain concentration of suspended sediment. Nothing is gained by leaving sediment concentrations in this range.

However, there is evidence that benefits may result when improvements occur to water which was of already acceptable quality (concentrations are below the thresholds). For instance, a decline in phosphorus concentrations will result in reduced algae growth rates, even when the initial concentration is below the threshold (0.1 milligrams per liter in this case) (24). This is likely to result in improved water clarity, and generate recreation benefits. Unfortunately, very little work has been done on linking recreation behavior or fishing success to small changes in water quality. Therefore, we assumed that benefits result only when predetermined threshold levels of pollutant concentrations are passed. This probably underestimates the benefits.

Offsite Benefit Estimates

When the data from the 1983 CRES records were processed, we found the present value of offsite benefits from reducing sheet and rill, gully, and streambank erosion on all land uses (cropland, pasture land and range land) to total $340 million, assuming a 4-percent discount rate (app. table 11). Based on the range of damage estimates presented in appendix table 11, the offsite benefits from erosion control on all agricultural land are likely to range between $201 and $508 million.

For the three damage categories outlined above, the best estimate of benefits from reduced damage to ditches and canals totaled $31 million, the benefits to water storage, flooding, navigation, and municipal and industrial withdrawal totaled $309 million, and the benefits to recreation and commercial fishing were zero. The reason for this last result is that the estimated reduction in soil erosion from the programs was so small that the estimated reductions in pollutant loadings were insufficient in any of the polluted ASA's to lower the ambient concentrations of suspended solids, nitrogen, and phosphorous below the threshold levels.

This last result may indicate problems in the procedures used. One of the drawbacks of an aggregate analysis such as this is that local improvements in water quality within a region would be missed. If most of the erosion reduction in a region were concentrated in a few ASA's, instead of being evenly distributed across a region, as was implicitly assumed, there would probably be a significant improvement in water quality in these ASA's. Positive benefits would then be generated in regions containing those ASA's.

Benefits were probably underestimated for the reasons outlined earlier; improvements in already acceptable water quality were assumed to generate no benefits. However, due to the small changes in water quality predicted for the programs, this downward bias in benefits is likely to be small.

There is another point to consider here. Even if erosion reductions were insufficient to reduce ambient pollutant concentrations below threshold levels, they do contribute to that goal. As future spending for soil conservation programs adds to the amount of land treated for soil erosion, Appendix table 11--Offsite benefit of erosion control on all agricultural land, 1983

Conservation program	Area treated 5/	Erosion reduction over time: Sheet and rill	Erosion reduction over time: Other	Erosion reduction over time: Total		Offsite benefits: Sheet and rill	Offsite benefits: Other	Offsite benefits: Total	Benefits per ton of erosion reduction	Benefits per acre treated for sheet and rill erosion
	1,000 acres	1,000 tons				1,000 dollars			Dollars	
CTA with ACP cost-					(low)	52,537	9,990	62,527	0.31	8.80
					(best)	87,717	16,905	104,622	.53	14.70
share 1/	5,967	164,547	33,531	198,078	(high)	129,540	25,266	154,806	.78	21.71
					(low)	108,784	8,714	117,498	.34	4.01
					(best)	184,572	14,307	198,879	.58	6.81
CTA only 2/	27,202	322,563	22,673	345,236	(high)	277,980	21,159	299,139	.87	10.25
ACP cost-					(low)	9,246	716	9,962	.46	13.42
share only					(best)	15,450	1,239	16,689	.77	22.42
3/	689	19,670	1,987	21,657	(high)	23,066	1,911	24,977	1.16	33.48
					(low)	11,092	96	11,188	.24	9.58
					(best)	19,183	167	19,350	.42	16.57
GPCP 4/	1,158	45,481	452	45,933	(high)	28,458	252	28,710	.62	24.58
					(low)	181,659	19,516	201,175	.33	5.20
					(best)	306,922	32,618	339,540	.55	8.79
Total 6/	35,016	552,261	58,643	610,904	(high)	459,044	48,588	507,632	.83	13.14

1/ Conservation Technical Assistance with Agricultural Conservation Program cost-share.
2/ Conservation Technical Assistance only.
3/ Agricultural Conservation Program cost-share only.
4/ Great Plains Conservation Program.
5/ Includes only acres treated for sheet and rill erosion.
6/ Columns may not add to totals because of rounding.

the cumulative effect could reduce pollutant concentrations below the threshold levels. The marginal improvements attributable to the 1983 programs could become important if the total cumulative costs over time are less than the expected recreation benefits. However, as new acreage is put under conservation practices, previously treated land may be losing its protection as the service lives of the practices expire. The net contribution to total erosion reductions by the 1983 programs is therefore less than indicated by the annual incremental analysis performed for this report.

The exclusion of offsite impacts of wind erosion from the analysis may result in little bias, due to the relatively small reductions in wind erosion from measures taken in 1983 (less than 2 percent in the five regions where wind erosion reductions were reported). There is also reason to expect a nonlinear relationship between wind erosion and damages, and that initially large reductions in erosion will achieve only relatively small levels of benefits.

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Soil Conservation and Farmland

Assessing Erosion on U.S. Cropland: Land Management and Physical Features, by Nelson L. Bills and Ralph E. Heimlich. AER-513. July 1984. 24 pp. $1.50. Order SN: 001-019-00341-3 from GPO.

Erosion from rainfall causes nearly 100 million acres of U.S. cropland to erode by more than 5 tons per acre per year. One-third of this land is so highly erosive that annual soil loss can be reduced to tolerable levels only under the most restrictive land management practices. More than one-third of U.S. cropland is inherently nonerosive under all management regimes, about half requires conservation management to keep soil loss within tolerable limits, and the remaining 8 percent is so erosive that acceptable soil loss rates cannot be achieved under intensive cultivation.

Do USDA Farm Program Participants Contribute to Soil Erosion? by Katherine H. Reichelderfer. AER-532. April 1985. 84 pp. $3.00. Order SN: 001-019-00383-9 from GPO.

Finds that only about one-third of U.S. cropland with excessive soil erosion rates is operated by farmers who might be influenced to reduce erosion if changes were made in USDA's commodity and soil conservation programs. Present commodity programs may conflict with conservation programs by encouraging cultivation of erosive crops. Efforts to increase the consistency of USDA commodity and conservation programs would contribute little to overcoming the Nation's total erosion problem.

Cropland Rental and Soil Conservation in the United States, by Nelson L. Bills. AER-529. March 1985. 20 pp. $1.50. Order SN: 001-019-00387-1 from GPO.

Data from USDA's Resource Economics Survey challenge the common but not well-substantiated view that farmers are less concerned with erosion on land they rent than on land they own. At the national level, farmers' conservation efforts on rented cropland compare favorably with those on owner-operated cropland.

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Agriculture's Links With U.S. and World Economies, by Alden C. Manchester. AIB-496. September 1985. 60 pp. $1.50. Order SN: 001-019-00409-6 from GPO.

Describes the linkages between farming and the supplying industries and those manufacturing and distributing farm products. Within the last 30 years, the food and fiber system has found itself increasingly reliant on nonfarm industries and increasingly affected by general economic developments, not only within the Nation but from overseas as well.

Improving U.S. Farmland, by Douglas Lewis and Thomas A. McDonald. AIB-482. November 1984. 12 pp. $1.00. Order SN: 001-019-00362-6 from GPO.

A clear, concise account of recent farmland improvements. Farmers invested more than $6.5 billion in improving their land in a recent 3-year period. Those investments, while often made on existing cropland, expanded total U.S. cropland by 9.1 million acres.

Major Uses of Land in the United States: 1982, by H. Thomas Frey and Roger W. Hexem. AER-535. June 1985. 36 pp. $1.25. Order SN: 001-019-00398-7 from GPO.

Discusses the major uses of the Nation's 2,265 million acres of land in 1982: cropland, 469 million acres; grassland pasture and range, 597 million acres; forest land (exclusive of areas in special-purpose uses), 655 million acres; special uses, 270 million acres; and miscellaneous other land, 274 million acres. Changes in cropland and pasture acreages were barely perceptible during 1978-82; forest land (except special use areas) and miscellaneous other land decreased sharply as large acreages in these categories were reclassified as parks, wilderness, and related uses.